

Aggregate Production Planning of Hybrid Corn Seed Using Heuristic Methods at PT CNM

Syamsul Anwar¹

Akademi Teknologi Industri Padang,
*syamsul.anwar01@alumni.ui.ac.id

Gus Ari Wardi²

Akademi Teknologi Industri Padang,
gusariwardi@gmail.com

ABSTRACT

PT CNM is a company producing hybrid corn seeds that located at Solok, West Sumatera. Fluctuating product demand, while the resources or factory's capacity were limited resulted in the company management face difficulties in making plans or production strategies that could meet customer demand. The purpose of this research is to make hybrid corn seed aggregate production planning with minimum total cost criteria. The approach used is to apply the aggregate production planning with heuristic methods. The first stage is to forecast demand for the 12 next months by using various of time series methods. The smallest value of the mean square error (SME) is used to selected the best forecast method. Finally the decomposition method is chosen to projected product demand. The second stage is to apply heuristic methods through pure strategies ; labour size control, inventory control, overtime, and a mixed strategy; overtime-subcontract. The comparison of total cost of these four strategies indicated that labour size control is the strategy with the minimum total cost. The application of these production strategies are given in more detail. The results of this study could help manager of company in making production planning.

Keywords: production planning, aggregate, heuristic methods.

INTRODUCTION

PT CNM is a company that producing hybrid corn seed. The factory is located at Solok town, West Sumatra Province, Indonesia. Marketing of product covers Sumatera, Java, Sulawesi and West Nusa Tenggara. Corn feedstocks are derived from corn plants around the factoryt in cooperated with farmer groups. The products of PT CNM are seed of corn to be used as animal feed, namely N-35 (size 1 kg) and N-37 (size 5 kg). Fluctuating product demand conditions, while the company has limited resources and production capacity makes the management have difficulty in making production planning to meet customer demand. So far the company in making production policy only rely on past sales records and intuition which is not measurable effectiveness and and efficiency.

In this case, aggregate planning is often used for the planning of production for product family. Aggregate planning is planning decisions in intermediate-term with time horizon of 3 months to 1 year. During this period, physical facilities of plant are assumed to be fixed (Kumar and Suresh, 2008) Aggregate planning focuses only on the family of products and not see individual items. (Waters,

2003) Aggregate planning is made to adjust production capacity in the face of uncertain market demand to optimize the use of resource (labour and production equipments) so that the total production cost can be reduced to minimum level. (Nasution, 2008). There are several strategies that can be implemented such as inventory planning, production level control, labour control, capacity control and others. If changes are made to a variable so that a change in the rate of production is called a pure strategy, such as inventory control, labour control, overtime, and sub-contract. Meanwhile a mixed strategy is use two or more pure strategies that production planning be more flexible. (Ginting, 2007)

In implementing this production strategy, there are some costs that arise as could be contributed to total production cost. Hiring cost is cost that arise from recruiting workers due to high product demand which it includes costs for advertising, recruitment process, and training workers. Whereas firing cost is costs that arise from laying off workers due to low product demand so that production rate will decrease drastically. Overtime cost is costs that arise from using work time out of normal work time to increase the production output. Overtime cost normally is higher than regular time cost. Inventory cost is cost that arise from holding inventory which to anticipate an increase in product demand at certain times. It is including capital costs, insurance, material damage cost, and warehouse rental fee. Lost sale cost are costs that arise from shortage of supplies so that product demand can not fulfilled. It is including costs of losing potensial revenues and losing consumer's trust. Sub-contract cost is cost due to transferring orders to other companies, it could happen due to limited capacity of the factory. Sub-contract cost is usually higher than regular production cost and overtime cost. (Sukendar, 2008).

The purpose of the research is to make an aggregate production planning of hybrid corn seeds at PT CNM which gives minimum total cost. Several previous studies that applied aggregate production planning, among others ; Chinguwa et al. (2013), Amri and Efrida (2010) used trial error (heuristic) methods and linear programming models, Kissani and El Mokrini (2012), Neureuther (2004), used linear programming, Purnomo (2010) made inventory planning and aggregate production planning used integer programming model. Wardani (2010) used linear transportation method. Octavianti et al. (2013) and Sukendar (2008) used heuristic methods. Based on previous researchs, heuristic methods and liniear programming models are the most widely method that used in solving problems of production planning in a firm. This study uses a heuristic method with a case study on an agricultural industry using heuristic methods by applying four types of production strategies; labour size control, inventory control, overtime, and overtime-subcontract.

RESEARCH METHOD

This study is a descriptive research with analysis is quantitatively. Data collection was carried out to PT CNM that is located at Solok town, West Sumatra Province, Indonesia. Methods of data collection is done by interviews to the managers of plant. The main data in this study is a secondary data of the company which is include product demand data year 2013, the number of workers, the data related to inventory policies, recruitment of employees, production capacity, hours of operation and overtime,

and others data related. Stage analysis is divided into two. Stage I is forecasting demand for year 2014 using time series methods with POM-QM software version 3. Stage II is applying aggregate planning strategies with heuristic methods (trial error) which is include four strategies ; labour size control, inventory control, overtime 1, and overtime sub-contract.

RESULTS AND DISCUSSION

The first stage is to forecast product demand for year 2014. The process of forecasting performed with quantitative approach. From data that obtained by the PT CNM in year 2013, demand for product N-35 and N-37 as where they can be seen in Table 1 below.

Table 1. Product demand in year 2013

Month-Year	Product demand (kg)	
	N-35	N-37
Jan-13	43.760	58.772
Feb-13	49.570	56.420
Mar-13	47.536	53.742
Apr-13	57.360	56.420
Mei-13	56.730	49.878
Jun-13	49.434	58.240
Jul-13	42.870	58.690
Agust-13	58.350	52.327
Sep-13	59.125	64.830
Okt-13	67.258	78.845
Nop-13	64.277	69.510
Des-13	59.882	71.656

Source : PT CNM, 2014

To simpifed in data processing to made production planning, data of product demand for both type of products are carried an aggregation process. Aggregate of data as instead of data individual family products. The approach in the process of aggregation is multiplying the amount of demand by selling price for each product. Selling price of product N-35 is Rp. 25,000 per kg, while for N-37 is Rp. 35,000 per kg. The aggregate data that was obtained, as can be be seen in Table 2 below.

Tabel 2. Aggregate demand

No	Month-Year	N-35	N-37	Aggregate Rp [000]
		Rp. (000)	Rp. (000)	
1	Jan-13	1.094.000.000	2.057.020.000	3.151.020
2	Feb-13	1.239.250.000	1.974.700.000	3.213.950
3	Mar-13	1.188.400.000	1.880.970.000	3.069.370
4	Apr-13	1.434.000.000	1.974.700.000	3.408.700
5	Mei-13	1.418.250.000	1.745.730.000	3.163.980
6	Jun-13	1.235.850.000	2.038.400.000	3.274.250
7	Jul-13	1.071.750.000	2.054.150.000	3.125.900
8	Agust-13	1.458.750.000	1.831.445.000	3.290.195
9	Sep-13	1.478.125.000	2.269.050.000	3.747.175
10	Okt-13	1.681.450.000	2.759.575.000	4.441.025
11	Nop-13	1.606.925.000	2.432.850.000	4.039.775
12	Des-13	1.497.050.000	2.507.960.000	4.005.010

Source : Own calculations, 2014

The pattern of product demand in year 2013 can be seen in Figure 1 below.

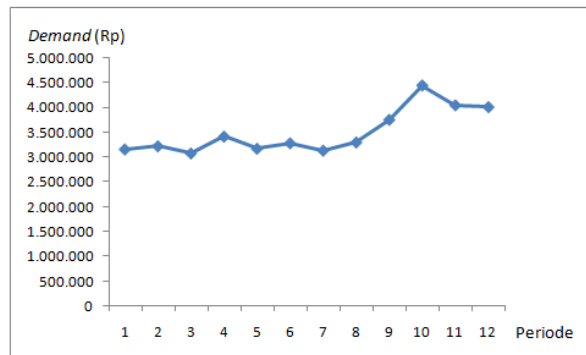


Figure 1. Product demand data year 2013

It can be seen that there are fluctuation in the data pattern and a trend upward. Then forecast demand was performed by five methods of times series ; *moving average-3*, *weighted moving average-3*, *exponential smoothing (alpha 0,8)*, *linear regression*, and *decomposition*. Indices performance for each forecasting method can be seen from the value of the Mean Square Error (MSE) as can be seen at Table 3 below.

Table 3. Recapitulation error forecasting results.

No.	Forecasting method	MSE
1	Moving average-3	171.115.100
2	Weighted moving average-3	160.539.700
3	Exponential smoothing	101.888.800
4	Linear Regression	69.389.740
5	Decomposition	66.353.740

Source : Own calculations, 2014

As can be seen in Table 3 above, decomposition method has the smallest MSE value thus it is selected for forecasting demand year 2014. Table 4 below shows the results of forecasting by the decomposition method.

Tabel 4. Forecast product demand year 2014

Month-Year	Aggregate (Kg)
Jan-14	138.237
Feb-14	137.354
Mar-14	144.547
Apr-14	148.176
Mei-14	146.998
Jun-14	154.464
Jul-14	158.114
Agust-14	156.642
Sep-14	164.380
Okt-14	168.053
Nop-14	166.286
Des-14	174.297

Source : Own calculations, 2014

From Table 4 above, data of product demand has been changed in unit kilograms. This is to simplifying in applying aggregat production planning.

Aggregate Planning by Heuristic Methods

The data was required in the aggregate production planning is the parameters of production on year 2013. Because of product demand in 2013 could be fullfilled so that product demand is assumed to be equal to the production capacity of the company. The parameters of production can be seen in Table 5 below.

Table 5. Parameters of production year 2013

Parameters of production year 2013	Quantity (kg)
1. Number of production in 1 year	1.385.482
2. Average production level per month	115.457
3. Average output level per worker per month (number of workers = 120 persons)	962,1
4. Average production level per day (1 periode = 26 day)	4.440,6
5. Output per worker per day	37
6. Output per worker per hour (2 shift = 16 hours)	2,3

Source : PT CNM and own calculations, 2014

Labour Size Control Strategy

To implement this strategy, production level was fitted to monthly demand. This can be done by controlling the amount of workers mainly direct workers. If product demand rises, it will be hiring workers, otherwise if product demand down then firing workers. Parameters such as labour cost are needed in the implementation of this strategy. The data can be seen in Table 6 below.

Table 6. Parameters of labour cost

Parameters of work force cost	Cost (Rp)
1. Wage of worker per month	1.300.000
2. Hiring cost per month is estimated 100% x regular wage per worker	1.300.000
3. Hiring cost per day	50.000
4. Hiring cost per hour (1 shift = 8 hours)	6.250
5. Hiring cost per kg (hiring cost per hour / 2,3 kg)	2.702
6. Firing cost per kg is estimated same with hiring cost	2.702

Source : PT CNM and own calculations, 2014

In January 2014, the number of labour can be calculated by dividing demand to output product per worker ; $138\,237\text{ kg} / 962.1\text{ kg} = 144$ workers. Hiring needs in unit kg can be calculated from demand rate of January that reduced to demand rate of previous month ; $138.237\text{ kg} - 131.538\text{ kg} = 6.699\text{ kg}$. While hiring needs in unit number of labour can be calculated from number of labour in January that reduced to number of labour on the previous month ; $(144 - 120)$ workers = 24 workers. Hiring need cost in January can be calculated from hiring need in unit kg multiplied with hiring need cost per worker ; $6.699\text{ kg} \times \text{Rp } 2702/\text{ kg} = \text{Rp. } 18.105.934$. Labour costs can be calculated by 144 workers \times Rp. 1.300.000 (wage) = Rp. 186.779.785. The total cost is sum of hiring need cost and labour cost ; $\text{Rp. } 18.105.934 + \text{Rp. } 186.779.785 = \text{Rp. } 204.885.720$. During the period of year 2014, there will be 8 months will need hiring of workers, while in the remaining 4 months will need firing workers. If a month need hiring workers then it means that firing workers will not occur. The total cost of this strategy is Rp 2.654.047.435. Detailed calculation can see appendix 1.

Inventory Control Strategy

For applying of this strategy, the production rate was set at the average demand level of year 2014 ; $154.796\text{ kg} / \text{month}$. If amount of production in a month excesses product demand then it will be stored as inventory. To find out when inventory is used clearly by looking at product demand pattern relatively to production level as can be seen in Figure 2 below.

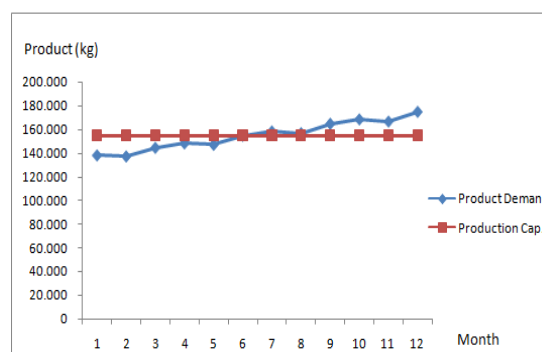


Figure 2. Product demand and production level

It can be seen from Figure 2 above, there will be excess production from January to June so that it will be hold as inventory. For the remaining months from July to December, the inventory will be used to

cover shortage of regular production. This will happen if the plant does not have initial inventory. Inventory cost is estimated at 5% of selling price of the products ; $5\% \times \text{Rp. } 30.000$ (average price of 2 types of products) = $\text{Rp. } 1.500/\text{ kg}$. Inventory level in January 2014 can be calculated from regular capacity reduced to product demand ; $154.796 \text{ kg} - 138.237 \text{ kg} = 16.559 \text{ kg}$. If it is multiplied by $\text{Rp. } 1.500 / \text{ kg}$ that will be obtained inventory cost $\text{Rp. } 24.837.826$. Increasing of production level in January 2014 will lead to hiring cost that can be calculated from regular capacity reduced to average production level in 2013 and multiplied by hiring cost per kg ; $(154.796 \text{ kg} - 115 457 \text{ kg}) \times \text{Rp. } 2702,7 / \text{ kg} = \text{Rp } 106.321.386$. The amount of workers during period 2014 is same due to production levels are fixed at each month. It can be calculated from the amount of regular capacity was divided by average output per worker ; $154.796 \text{ kg} / 962.1 \text{ kg} = 161$ workers. The labour cost can be calculated from amount of workers was multiplied by wage; $152 \text{ workers} \times \text{Rp. } 1,300,000 = \text{Rp. } 197.600.000$. Total cost is sum of inventory cost, hiring cost, and labour cost ; $\text{Rp. } 11,017,761 + \text{Rp } 81.420.458 + \text{Rp. } 197.600.000 = \text{Rp. } 290.038.219$.

Inventory level of February can be calculated from (inventory level of previous month + production level in February – product demand) ; $16.559 \text{ kg} + 154.796 \text{ kg} - 137.354 \text{ kg} = 34.000 \text{ kg}$. Inventory cost is $34.000 \text{ kg} \times \text{Rp. } 1,500 / \text{ kg} = \text{Rp. } 28.825.023$. There will be no hiring costs due to the amount of workers are constant during year 2014 period. The next cost calculations are same as previously described. The total cost of this strategy is $\text{Rp } 3.317.660.855$. Detailed calculation can see appendix 2.

Overtime Strategy

For applying of this strategy by setting a fixed monthly production rate based on the lowest product demand level at 137.354 kg . Next, average output per day can be calculated by $137.354 \text{ kg} / 26 \text{ days} = 5282,8 \text{ kg}$. Average output per hour is $5282,8 \text{ kg} / 16 \text{ hours (for 2 shifts)} = 330,2 \text{ kg}$. Overtime policy of company was limited at 1 hour per day or 26 hours per month. The maximum capacity of overtime production can be calculated ; $26 \text{ hours} \times 330,2 \text{ kg (average output per hour)} = 8.585 \text{ kg per month}$. The overtime cost is $\text{Rp. } 15,000$ per hour per worker or $\text{Rp. } 1,800,000$ per hour per 120 workers.

In January 2014 there will be shortage of regular capacity ; $138.237 \text{ kg} - 137.354 \text{ kg} = 883 \text{ kg}$ or in hours unit can be calculated from $883 \text{ kg} / 330,2 \text{ kg} = 3 \text{ hours}$. Overtime costs can be calculated by $3 \text{ hours} \times \text{Rp. } 1,800,000$ (overtime cost) = $\text{Rp. } 4.813.732$. The labour cost of 120 workers is $\text{Rp. } 156,000,000$. In this period will not occur lost sale, product demand can be fulfilled by regular and overtime capacity. The total cost is sum of overtime costs and labour cost ; $\text{Rp } 4.813.732 + \text{Rp. } 156.000.000 = \text{Rp. } 160.813.732$ It can be seen in appendix 3, there will be 9 months occur lost sale or product demand can not be met. In April, there will be lost sale due to product demand excess overtime capacity ; $10.882 \text{ kg} - 8.585 \text{ kg} = 2.237 \text{ kg}$ or $33 \text{ hours} - 26 \text{ hours} = 7 \text{ hours}$. Lost sale cost need to considered and estimated due to losses of sales revenues and goodwill from customers. Lost sale cost is estimated $\text{Rp. } 5,000 / \text{ kg}$. In April, lost sale cost is $2.237 \text{ kg} \times \text{Rp. } 5000 / \text{kg} = \text{Rp. } 11.184.801$. The overtime cost is calculated as $26 \text{ hours} \times \text{Rp. } 1,800,000 \text{ per hour} = \text{Rp } 46.800.000$. The total cost of this strategy is $\text{Rp } 2.957.030.879$. Detailed calculation can see appendix 3.

Overtime and Sub-contract Strategy

If product demand can not be fulfilled by regular and overtime capacity, the company will perform the transfer orders to other companies (sub-contract). Sub-contract cost is estimated 125% times overtime cost ; $125\% \times \text{Rp. } 1800.000 = \text{Rp. } 2,250,000$ / hour. The advantage of this strategy is lost sale can be overcome by sub-contract. Same as overtime strategy, sub-contract will performed in April at 2.237 kg or 7 hours. The sub-contract cost can be calculated as 7 hours x Rp. 2,250,000 (sub-contract cost) = Rp. 15.243.762. Total cost is sum of overtime cost, lost sale cost and labour cost. The total cost of this strategy is Rp 3.181.958.545. Detailed calculation can see appendix 4.

Comparison of Strategies

Application of each strategy produces different characteristics. For more details, can see the production parameters of each strategy by looking at table 7 below.

Tabel 8. Production Parameters of four production strategies

Production Parameters	Strategy			
	1	2	3	4
Type of labor size	flexible	constant	constant	constant
Labour size (person)	143 - 181	161	120	120
Type of production	flexible	constant	constant	constant
Total regular production cap.(kg)	1.857.549	1.857.549	1.648.250	1.648.250
Total inventory (kg)	0	467.599	0	0
Total overtime cap. used (kg)	0	0	85.337	85.337
Lost sale (kg)	0	0	123.961	0
Sub-contract (kg)	0	0	0	123.961

Source : own calculations, 2014

There are some similarities and differences in the types of costs arising from each strategy as can be seen at Table 8 below.

Tabel 8. Cost Parameters of four production strategies

Cost Parameters (Rp)	Strategy			
	1	2	3	4
Hiring/ Firing	144.212.126	106.321.386	0	0
Labour	2.509.835.310	2.509.940.382	1.872.000.000	1.872.000.000
Inventory	0	701.399.087	0	0
Overtime	0	0	465.224.180	465.224.180
Lost sale	0	0	619.806.698	0
Sub-contract	0	0	0	844.734.365
Total cost	2.654.047.435	3.317.660.855	2.957.030.879	3.181.958.545

Nb : 1 : labor size control, 2 : inventory control, 3 : overtime, 4 : overtime and sub-contract

Source : own calculations, 2014

From Table 8 above, labour cost is significant factor that contribute to total cost for all strategies. Hiring/firing cost are arise on strategy-1 and strategy-2. Inventory cost is only arise on strategy-2. Overtime cost is arise on strategy-3 and strategy-4. Lost sale cost is only arise on strategy-3. Sub-contract cost is only arise on strategy-4. Overall, strategy-1 (labor size control) has smallest total cost at Rp. 2.654.047.435 so that this strategy is recommended to implemented for PT CNM.

CONCLUSION

This study has applied four type aggregate production strategies to the problems of PT CNM. Strategies are clustered in heuristic methods ; labour control strategy, inventory control strategy, overtime strategy, overtime and sub-contract strategy. These strategies each produce different total cost. Labour control strategy is the best strategy that generates the minimum total cost at Rp. 2.654.047.435. This research can be developed by analyzing how changes of total cost strategies due to changing in cost parameters (sensitivity analysis). This study uses only total production cost as a performance criteria of each strategy. Further research can focus to various aspects in selecting production strategy based on their advantages and disadvantages such as ease of implementation and quality risk.

APPENDIX

Appendix 1. Labor size control strategy

Month-year	Demand (Kg)	Worker	Hiring need			Firing need			Labour cost (Rp)	Total cost (Rp)
			(kg)	(worker)	cost (Rp)	(kg)	(worker)	cost (Rp)		
Jan-14	138.237	144	6.699	24	18.105.934	0	0	0	186.779.785	204.885.720
Feb-14	137.354	143	0	0	0	883	1	2.386.472	185.586.723	187.973.195
Mar-14	144.547	150	7.192	7	19.439.102	0	0	0	195.304.857	214.743.959
Apr-14	148.176	154	3.629	4	9.808.460	0	0	0	200.208.372	210.016.832
Mei-14	146.998	153	0	0	0	1.178	1	3.182.766	198.617.221	201.799.987
Jun-14	154.464	161	7.465	8	20.176.630	0	0	0	208.704.065	228.880.695
Jul-14	158.114	164	3.651	3	9.867.137	0	0	0	213.636.914	223.504.051
Agust-14	156.642	163	0	0	0	1.472	1	3.978.882	211.647.764	215.626.645
Sep-14	164.380	171	7.738	8	20.914.158	0	0	0	222.103.318	243.017.476
Okt-14	168.053	175	3.673	4	9.925.725	0	0	0	227.065.457	236.991.181
Nop-14	166.286	173	0	0	0	1.767	2	4.775.087	224.678.262	229.453.348
Des-14	174.297	181	8.011	8	21.651.775	0	0	0	235.502.571	257.154.345
	1.857.549				129.888.920			14.323.206	2.509.835.310	2.654.047.435

Source : Own calculations, 2014

Appendix 2. Inventory control strategy

Month-year	Demand (kg)	Regular cap. (kg)	Shortage of Regular cap. (kg)	Inventory		Worker	Hiring cost (Rp)	Labour cost (Rp)	Total cost (Rp)
				(kg)	cost (Rp)				
Jan-14	138.237	154.796		16.559	24.837.826	161	106.321.386	209.161.699	340.320.911
Feb-14	137.354	154.796		34.000	51.000.143	161	0	209.161.699	260.161.842
Mar-14	144.547	154.796		44.249	66.373.759	161	0	209.161.699	275.535.458
Apr-14	148.176	154.796		50.869	76.303.680	161	0	209.161.699	285.465.379
Mei-14	146.998	154.796		58.667	88.000.036	161	0	209.161.699	297.161.734
Jun-14	154.464	154.796		58.999	88.498.362	161	0	209.161.699	297.660.061
Jul-14	158.114	154.796	3.319	55.680	83.520.428	161	0	209.161.699	292.682.126
Agust-14	156.642	154.796	1.846	53.834	80.750.772	161	0	209.161.699	289.912.471
Sep-14	164.380	154.796	9.585	44.249	66.373.759	161	0	209.161.699	275.535.458
Okt-14	168.053	154.796	13.257	30.992	46.487.969	161	0	209.161.699	255.649.668
Nop-14	166.286	154.796	11.490	19.502	29.252.352	161	0	209.161.699	238.414.051
Des-14	174.297	154.796	19.502	(0)	(0)	161	0	209.161.699	209.161.699
		1.857.549		467.599	701.399.087		106.321.386	2.509.940.382	3.317.660.855

Source : Own calculations, 2014

Appendix 3. Overtime control strategy

Month-year	Demand (kg)	Regular cap. (kg)	Shortage of Reg. Cap.		Max. OT cap.		Shortage of OT Cap.		Lost sale cost (Rp)	OT cost (Rp)	Labour		Total cost (Rp)
			(kg)	(hour)	(hour)	(kg)	(kg)	(hour)			(worker)	Cost (Rp)	
Jan-14	138.237	137.354	883	3	26	8.585				4.813.732	120	156.000.000	160.813.732
Feb-14	137.354	137.354	0	0	26	8.585				0	120	156.000.000	156.000.000
Mar-14	144.547	137.354	7.192	22	26	8.585				39.210.448	120	156.000.000	195.210.448
Apr-14	148.176	137.354	10.822	33	26	8.585	2.237	7	11.184.801	46.800.000	120	156.000.000	213.984.801
Mei-14	146.998	137.354	9.644	29	26	8.585	1.059	3	5.296.684	46.800.000	120	156.000.000	208.096.684
Jun-14	154.464	137.354	17.109	52	26	8.585	8.525	26	42.623.449	46.800.000	120	156.000.000	245.423.449
Jul-14	158.114	137.354	20.760	63	26	8.585	12.176	37	60.877.653	46.800.000	120	156.000.000	263.677.653
Agust-14	156.642	137.354	19.288	58	26	8.585	10.703	32	53.516.722	46.800.000	120	156.000.000	256.316.722
Sep-14	164.380	137.354	27.026	82	26	8.585	18.442	56	92.207.913	46.800.000	120	156.000.000	295.007.913
Okt-14	168.053	137.354	30.699	93	26	8.585	22.114	67	110.570.504	46.800.000	120	156.000.000	313.370.504
Nop-14	166.286	137.354	28.932	88	26	8.585	20.347	62	101.736.594	46.800.000	120	156.000.000	304.536.594
Des-14	174.297	137.354	36.943	112	26	8.585	28.358	86	141.792.377	46.800.000	120	156.000.000	344.592.377
		1.648.250				85.337	123.961		619.806.698	465.224.180	1.440	1.872.000.000	2.957.030.879

Source : Own calculations, 2014

Appendix 4. Overtime and sub-contract strategy

Month-year	Demand (kg)	Regular cap. (kg)	Shortage of Reg. Cap.		Max. OT cap.		Shortage of OT Cap.		Sub-contract cost (Rp)	OT cost (Rp)	Labour		Total cost (Rp)
			(kg)	(hour)	(hour)	(kg)	(kg)	(hour)			(worker)	Cost (Rp)	
Jan-14	138.237	137.354	883	3	26	8.585				4.813.732	120	156.000.000	160.813.732
Feb-14	137.354	137.354	0	0	26	8.585				0	120	156.000.000	156.000.000
Mar-14	144.547	137.354	7.192	22	26	8.585				39.210.448	120	156.000.000	195.210.448
Apr-14	148.176	137.354	10.822	33	26	8.585	2.237	7	15.243.762	46.800.000	120	156.000.000	218.043.762
Mei-14	146.998	137.354	9.644	29	26	8.585	1.059	3	7.218.849	46.800.000	120	156.000.000	210.018.849
Jun-14	154.464	137.354	17.109	52	26	8.585	8.525	26	58.091.487	46.800.000	120	156.000.000	260.891.487
Jul-14	158.114	137.354	20.760	63	26	8.585	12.176	37	82.970.135	46.800.000	120	156.000.000	285.770.135
Agust-14	156.642	137.354	19.288	58	26	8.585	10.703	32	72.937.924	46.800.000	120	156.000.000	275.737.924
Sep-14	164.380	137.354	27.026	82	26	8.585	18.442	56	125.670.138	46.800.000	120	156.000.000	328.470.138
Okt-14	168.053	137.354	30.699	93	26	8.585	22.114	67	150.696.507	46.800.000	120	156.000.000	353.496.507
Nop-14	166.286	137.354	28.932	88	26	8.585	20.347	62	138.656.774	46.800.000	120	156.000.000	341.456.774
Des-14	174.297	137.354	36.943	112	26	8.585	28.358	86	193.248.789	46.800.000	120	156.000.000	396.048.789
		1.648.250				85.337	123.961		844.734.365	465.224.180		1.872.000.000	3.181.958.545

Source : Own calculations, 2014

ACKNOWLEDGEMENTS

The authors would like to thank for suggestions from anonymous reviewers in improvement of this research. Thanks to PT CNM's management who have supported the data for this research.

REFERENCES

- Amri, T. H. and Efrida N., *Perencanaan Pengendalian Produksi Air Minum Dalam Kemasan Menggunakan Metode Agregat Planning*, Malikussaleh Industrial Engineering Vol.1 No.1, pp : 11-18, 2012
- Chinguwa, S., Madanhire, I., Musoma, T. A Decision Framework based on Aggregate Production Planning Strategies in a Multi Product Factory : A Furniture Industry Case Study, *International Journal of Science and Research (IJSR)*, Vol.2 Issue 2, pp : 370-383, 2013

- Ginting, R., *Sistem Produksi*, Graha Ilmu, Jakarta, 2007.
- Kissani, I. And El Mokini, A., Aggregate Planning : Opportunities and Challenges between Developed and Developing Countries. *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management*, Istanbul, Turkey , pp : 1848 – 1855, 2012
- Kumar, S. A., and Suresh, N., *Production and Operation Management*, New Age International Publishers, New Delhi, 2008
- Nasution, A.H., “*Manajemen Industri*”, Penerbit Andi, Yogyakarta , 2006.
- Neureuther, B.D. , Aggregate Planning in Make-to-Order Environments, *Proceedings of the Second World Conference on POM and 15th Annual POM Conference*, Cancun, Mexico , pp : 1 – 15, 2004
- Octavianti, I. A., Setyanto, N. W., Tantrika, Ceria F. M., Perencanaan Produksi Agregat Produk Tembakau Rajang P01 dan P02 di PT X, available at <http://jrmsi.studentjournal.ub.ac.id/index.php/jrmsi/article/download/33/56>, diakses pada 5 Agustus 2014
- Purnomo, A. Perencanaan Produksi dan Pengendalian Persediaan Bahan Baku pada Pengrajin Tahu dan Tempe ”IM” Cibogo Bandung, *Jurnal Logistik Bisnis Politeknik*, Vol.1, No.1, pp : 97 – 117, 2010
- Sukendar, I, Metode Perencanaan Aggregate Plannig Heuristik sebagai Perencanaan dan Pengendalian Produksi Untuk Minimasi Biaya, *Prosiding Seminar Nasional Teknoin*, Universitas Islam Sultan Agung, Semarang , pp : C107 – C-112, 2008
- Wardhani, A. R., Perencanaan Agregat dengan Metode Transportasi pada PT X Pasuruan, *Widya Teknika*, Vol.18, No.1, pp : 6 – 10, 2010
- Waters, D., *Inventory Control and Managemen*, John Wiley & Sons Ltd, Chicester, UK, 2003