Saudi Journal of Business and Management Studies (SJBMS)
Scholars Middle East Publishers
Dubai, United Arab Emirates
Website: https://saudijournals.com/
ISSN 2415-6663 (Print)
ISSN 2415-6671 (Online)

Optimization of Transformer Production Cost Using Mixed Integer Linear Programming

Isnen Ristumadin dan Niken Sulistyowati*
Master of Management Program Graduate University of Mercu, Buana, Indonesia

***Corresponding author**
Isnen Ristumadin dan Niken Sulistyowati

Article History
Received: 03.11.2018
Accepted: 07.11.2018
Published: 30.11.2018

DOI:
10.36348/sjbms.2018.v03i11.003

Abstract: This study aims to determine the amount of transformer production, availability of labor, inventory of finished products, normal working hours and optimal overtime so as to obtain minimal production costs and increase company profits. The method used in this study is to use Aggregate Planning by optimizing mixed integer linear programming. The data used is the secondary data of the company, then developed with mathematical models and processing data using the help of LINDO 6.1 software. The results of the study are as follows: 1.) The optimal number of production at (normal working hours and overtime) is 141 units of product, 2.) The optimal number of workers is that there are 173 employees or companies do not need to increase or decrease the number of employees, 3.) The optimal number of finished product inventories is 69 units. 4.) The need for normal working hours and optimal overtime decreases from 201,541 to 193,755 people working hours or decreases by 4%, 5.) Optimization of minimizing transformer production costs is 4.6% or Rp. 57,661,862,889, - from Rp. 1,249,002,284,528, - to Rp 1,191,340,421,639, -.
Keywords: Optimization, Aggregate Planning, Mixed integer linear programming, Lindo 6.1, Minimum cost.

INTRODUCTION

To achieve effectiveness and efficiency in manufacturing operations, there must be optimization of existing resources as a strategic issue in the organization because it contributes to profits.

In dealing with the above conditions, it is necessary to increase the level of productivity, capability, and efficiency in each production line, so that a production plan is needed that can maximize the availability of resources so as to minimize production costs in increasing company profits [1].

Aggregate production planning is a planning process that can balance the uncertainty of customer demand with the availability of resources in a short and medium term plan by minimizing the total production costs required or maximizing the profits obtained by the company [2]. The planning of aggregate production of a company can be done in various ways according to the conditions and situation of the company. Production planning can be done by quantitative analysis of customer demand both in quantity and schedule of fulfillment, available material, production capacity and other available resources. In the management of a factory, a production manager must make decisions about the right production plan for the future period [3]. Buxey [4] explains in the planning of aggregate production, there are strategies that can be done in meeting customer demand and company supply. The strategy of employing labor and the level of product inventory is the most common strategy choice for companies. The strategy of using labor will cause inventory to be low, so the cost of handling inventory becomes low, but labor costs are higher. Liu & Tu [5] explained that increasing inventory levels can meet customer demand and avoid losing sales. However, this can cause storage costs to increase. Vice versa, if the company does not or lacks inventory, it will cause service to customers to be not optimal. Therefore, optimal production planning is needed in meeting customer demand and supply by utilizing the maximum available resources.

LITERATURE REVIEW

Aggregate production planning is a planning process that is formed by utilizing the maximum available resources to meet customer demand. In aggregate planning, optimal inventory levels are set, shortening the time of delivery of goods, and stabilizing the rate of production and helping Top Management in running the company's business. Aggregate production planning is designed to help companies balance the meeting between demand and supply of goods to customers [2]. Aggregate planning is a tool to identify operational parameters within a certain period of time as follows: a. the level of production is the sum of each in a unit of time (such as per day, per week, per month), b. The optimum amount of labor needed, adjusted to customer demand for production capacity, c. Overtime hours are additional working hours outside of regular working hours in carrying out production., d. Sub-contracting is the use of third parties in increasing production capacity. E. Backlog is a request that cannot be fulfilled within a certain time period, but is included in the next period of production planning; f. Inventory is the level of inventory that will be used to meet demand in the next period.

Chase, *et al*. [2] write that aggregate production planning is related to the determination of the rate of production through product groups or other components for medium-term planning (3-18 Months). The main objective of aggregate planning is to determine the optimal conditions between the rate of production, the amount of labor requirements, and the amount of inventory. The production rate refers to the number of product units that have been completed in the unit unity production within a certain time (per hour or per day). The amount of labor is the amount of labor needed to do production (production = rate of production x number of workers). The amount of inventory is the number of products stored, which are not sold in the previous sales period.

With a broader definition, aggregate planning has the following characteristics: 1). The planning period is intermediate 3-12 months with adjustments every month. 2). Customer demand or demand always fluctuates, is uncertain and sometimes has seasonal characteristics. 3). The possibility of a change between customer demand and the company's supply. 4). Affect management decisions that include the level of production, inventory, labor requirements, costs, flexibility and service to customers.

There are various strategies that companies can do in planning aggregate production. Buxey [4] categorizes the strategies of certain product companies in planning their aggregate production: 1). Chase strategy where the demand is adjusted to the regulation of the rate of production, labor and subcontracting to third parties. Buxey [4] argues the use of chase strategy is very suitable for high-value, perishable products, it is difficult to store as inventory and the product has a very large variety. 2). Modified chases are carried out as an alternative to chase strategy where when limited resources become an obstacle to production levels in the face of market demand. In the modified chase strategy the company carries out several stockpiles of the most demanded product variants, and ignores products that are considered to have low demand. 3). Level strategy where the production capacity of each period is fixed. This strategy is called fostering inventory to anticipate an increase when the demand period is high. Buxey [4] argues that companies use this strategy because employees need a long time to become experts in their fields. 4). Demand management strategy where this strategy is the way the company applies to launch various complementary products when the company is in the off season. 5). Labor management is a step in the company's management decision to avoid the risk of using permanent employees. It would be more useful to use temporary labor as their employees, but this strategy depends on the nature of the company's business, the job training provided and the desired level of production.

Buxey [4] argues that the majority of industries are chase strategies in meeting demand and supply. Using this strategy, inventory will be low so that the cost of handling inventory becomes low, but results in higher labor costs. Liu & Tu [5] explained that increasing inventory levels can meet customer demand and avoid losing sales. However, this can cause storage costs to increase. Vice versa, if the company does not have or lack of inventory, it will cause service to customers to be not optimal. Therefore, optimum production planning is needed in meeting customer demand and supply. Aggregate production planning establishes a plan with the aim of lowering total production costs or increasing company profits.

Aggregate planning strategies can be combined to find optimum conditions in production planning. In preparing the aggregate planning, first of all it is necessary to forecast the production capacity as a basis for production planning, so that forecasting methods are needed that best suit the fluctuations of customer demand. After the basis of production planning has been predicted, then an appropriate strategy is adjusted to bring together the company's supply and customer demand [6]. Mixed Integer Linear Programming is an extension of Linear Programming, where in Mixed Integer Linear Programming there is a combination of variables that are valued at real numbers, integers and binary numbers. In general Mixed Integer Linear Programming (MILP) is a technique that has been widely adopted by all companies in the planning of aggregate production. Mixed Integer Linear programming requires several assumptions to be able to complete aggregate production planning. Mixed Integer Linear programming has the following characteristics: 1). Customer demand is deterministic, 2). The production costs for each plan are assumed to be fixed., 3). Costs that arise as a result of changes in the rate of production in each period, are also assumed to be fixed., 4). Inventory levels can be limited during the planning period. 5). Inventory costs can be varied during the planning period., 6). Every single production facility only serves one market. But along with the increasing complexity of business competition, this is trying to be developed by Al-e-hashem *et al*. [7] which developed stochastic models integrated with linear programming in planning aggregate production for products that have multi-product characteristics that have work in various places. 7). Backorders may be included in planning, but usually cannot be done. Very competitive competition requires companies to make efficient their operations by allocating limited resources. Limited production of a company, followed by fluctuations in demand in certain months makes Liu & Tu [5] develop a stockout strategy model to balance the demand and supply of customers with availability limitations integrated with the polynomial time complexity algorithm model.

METODE

The type of this research is a descriptive study of predictive studies. The problems experienced in PTAID's imbalance between the number of orders and the availability of available resources in certain months led to the need for optimization of production planning which aims to minimize the production costs of transformers in PTAID, so production planning is needed to bring together demand and supply by optimizing availability of available resources. The problem formulated in this study is how to determine optimum strategies to deal with the limitations of production capacity experienced by PTAID in its production planning. With optimum production planning, it is expected that the total costs involved become minimum while still considering the fulfillment of customer demand priorities.

The research steps are depicted in a flow chart as shown in **Figure 1**.

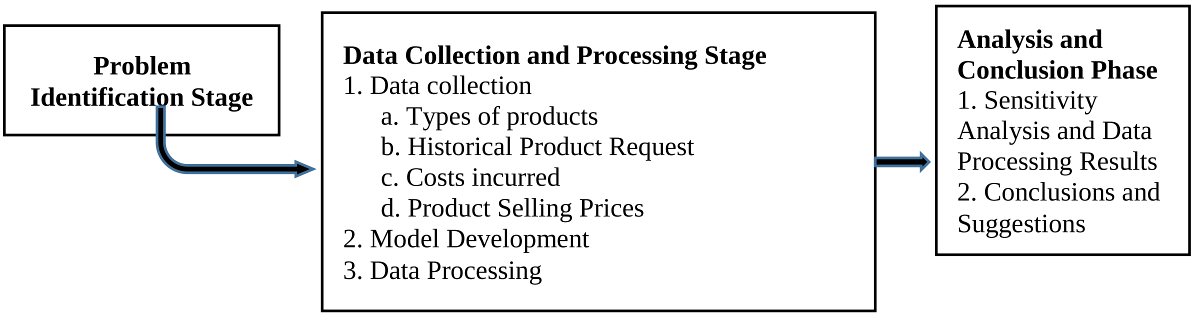

Fig-1: Research Flow Chart

From the flow chart of image 1 the process of collecting the data needed in this study was obtained from company records and from interviews with PTAID Management. a. There are 26 types of products grouped in PTAID which will be the subject of discussion in this study. Where 26 types of products are 30 MVA, 60 MVA, 100 MVA, 250 MVA and 500 kV which are all types of products through 9 different processes, namely Insulation material, Winding, Core Stacking, Core Coil Assembly, Lead Conection, Oven (VPD), Final Assembly, Testing, and Finishing. These PTAID products have different employee needs and have different processing times for each process, b. From historical data collected the number of production in 2014 to 2017 were 134 units, 136 units, 123 units, 127 units and 141 units, c. The components of Transformer's production costs are operational costs (asset and monthly costs) and storage costs. These costs greatly affect the operational performance of the Transformer production process. The details of the components of operational costs are as follows: 1. The company's operating activities include packaging costs, and transportation costs, 2. Regular labor costs, overtime labor costs, labor recruitment fees and labor reduction costs, 3. Monthly fees are cost components issued every month regularly to support operational activities of transformer production. Components that include monthly costs are overhead in the form of management salary, electricity and water costs, etc. 4. Inventory costs are costs incurred in storing inventory, 5. Storage costs (holding cost / carrying cost), namely costs incurred because the company keeps inventory. Storage costs are very dependent on the quantity of goods stored, 6. The cost of assets is all costs that include aspects of equipment and the place to carry out operational activities of Transformer production. This cost is also a critical matter because without the cost of assets, production activities cannot run. d. Transformer prices sold range from 3.2 billion to 23.9 billion rupiah.

Model development is a process of analysis and selection of alternative mathematical equations that are expected to describe the real conditions of the production system and optimize the company's profits. Selection of the model to take into account the variables contained in the model, then do the calculation, and analyze the feasibility of the calculation results. Based on these criteria, a mixed integer linear programming model is used by Takey & Mesquita [8] in production planning that has variations in overtime hour, workforce, and inventory. Where these strategies according to researchers have similar conditions that occur in PTAID.

The mathematical model making that will be used in this research is

Minimize production costs z = product operating costs i (regular + overtime) + product inventory costs i + normal time labor costs + overtime labor costs + additional and reduced labor costs.

Or in mathematical programming language

$$min\, z = \sum_{i=1}^{m=12}\sum_{t=1}^{T=12} mi\,.(Xit + Yit) + \sum_{i=1}^{m=12}\sum_{t=1}^{T=12} Ii\,.Iit + \sum_{i=1}^{m=12}\sum_{t=1}^{T=12} wi\,.Wi + \sum_{i=1}^{m=12}\sum_{t=1}^{T=12} ui\,.Uit - \sum_{t=}^{T=12}(h\,.Ht + f\,.\,Ft)$$

Index
i : Product type t: Period (12 Months)
Decision Variable
Xit : The total amount of production i regular work time during period t (unit).
Yit : The total amount of production i overtime during the period t (unit).
Iit : Amount of inventory of product i stored during period t (unit).
Wit : The need for a regular number of hours of product work at the t-period (man-hour).
Uit : The number of hours needed to work overtime products at the man-hour period.
Ht : The number of workers recruited during the period t (man).
Ft : The amount of labor reduced during the period t (man).
Mant : The amount of labor needed during the period t (man).

Parameter
Dit : The number of product requests i during the period t (unit).
mi : Monthly operating costs and asset costs excluding labor costs for each type of product i (rupiah per unit).
li : The cost of storing each type of product i (rupiah per unit).
wi : Normal hourly labor costs for producing products (rupiah per man-hour).
ui : Hourly labor costs overtime to produce products (rupiah per man-hour).
h : Additional labor costs (rupiah per man).
f : Cost of labor reduction (rupiah per man).
pi : Time of product processing unit i (man-hour per unit).
AvRt : Availability of regular working hours during the t (hour) period.
AvOt : Availability of overtime working hours during the t (hour) period.
Max : Maximum number of employees allowed (man).

RESEARCH RESULTS AND DISCUSSION

Research result, this research was conducted at PTAID, a manufacturing company that produces transformers with a total of 141 units in the period April 2017 - March 2018. From the results of data collection can be known as presented in tabel 2.

Table-2: Data on operational costs, inventory, total costs, selling prices, margin, Cycle Time and Man Power Cost

No	Variable	Description	Operation Cost (Rp)	Inventory Cost (Rp)	Material (Rp)	Total Cost (Rp)	Product Price (Rp)	Margin (Rp)	Cycle Time (days)	Man hours Total	Manpower Cost per Hour (Normal)	Manpower Cost per Hour (Over Time)
1	X1	10 MVA 110/11 kV	1.252.518.782	93.220.520	4.474.584.953	5.820.324.255	6.958.437.680	1.138.113.425	27	820	25000	40000
2	X2	10 MVA 33/11 kV	1.080.006.299	77.500.452	3.720.021.696	4.877.528.447	6.000.034.994	1.122.506.547	17	780	25000	40000

No	Variable	Description	Operation Cost (Rp)	Inventory Cost (Rp)	Material (Rp)	Total Cost (Rp)	Product Price (Rp)	Margin (Rp)	Cycle Time (days)	Man hours Total	Manpower Cost per Hour (Normal)	Manpower Cost per Hour (Over Time)
3	X3	100 MVA 150/66 kV	2.592.406.994	176.838.243	8.488.235.642	11.257.480.879	14.402.261.079	3.144.780.200	27	1741	25000	40000
4	X4	100 MVA 150/70 kV	2.592.406.994	181.115.764	8.693.556.664	11.467.079.422	14.402.261.079	2.935.181.656	27	1604	25000	40000
5	X5	100 MVA 150/70/10 kV	2.435.726.305	172.210.103	8.266.084.936	10.874.021.344	13.531.812.808	2.657.791.464	27	1604	25000	40000
6	X6	120 MVA 220/114/11 kV	3.139.226.172	225.987.688	10.847.409.019	14.212.622.879	17.440.145.400	3.227.522.521	29	1446	25000	40000
7	X7	135 MVA 150/20 kV	2.279.282.155	199.318.177	9.567.272.480	12.045.872.812	12.662.678.640	616.805.828	37	2067	25000	40000
8	X8	167 MVA 500/150 kV	4.314.774.425	259.627.916	12.462.139.968	17.036.542.308	23.970.969.027	6.934.426.719	56	3137	25000	40000
9	X9	20 MVA 33/11 kV	1.047.668.313	61.453.688	2.949.777.036	4.058.899.037	5.820.379.517	1.761.480.479	19	867	25000	40000
10	X10	20 MVA 33/66 kV	651.682.440	39.975.890	1.918.842.740	2.610.501.070	3.620.458.000	1.009.956.930	18	715	25000	40000
11	X11	215 MVA 150/11 kV	592.200.000	40.020.186	1.920.968.924	2.553.189.110	3.290.000.000	736.810.890	22	944	25000	40000
12	X12	23 MVA 66/11 kV	1.524.480.980	70.365.304	3.377.534.586	4.972.380.870	8.469.338.776	3.496.957.906	25	922	25000	40000
13	X13	24 MVA 33/11 kV	834.608.338	63.120.727	3.029.794.896	3.927.523.961	4.636.712.989	709.189.028	21	887	25000	40000
14	X14	250 MVA 220/110/11 kV	3.466.554.120	265.492.339	12.743.632.278	16.475.678.737	19.258.634.000	2.782.955.263	47	3087	25000	40000
15	X15	30 MVA 150/20 kV	1.152.659.704	79.491.102	3.815.572.874	5.047.723.679	6.403.665.020	1.355.941.340	30	960	25000	40000
16	X16	30 MVA 150/22 kV	1.351.492.363	93.836.940	4.504.173.118	5.949.502.421	7.508.290.905	1.558.788.484	22	965	25000	40000
17	X17	30 MVA 66/22 kV	1.296.203.485	93.815.439	4.503.141.082	5.893.160.005	7.201.130.470	1.307.970.465	22	954	25000	40000
18	X18	30 MVA 66/23 kV	1.672.569.000	101.805.488	4.886.663.434	6.661.037.922	9.292.050.000	2.631.012.078	22	954	25000	40000
19	X19	30 MVA 70/22 kV	1.093.016.247	85.723.008	4.114.704.371	5.293.443.625	6.072.312.482	778.868.857	22	954	25000	40000
20	X20	5 MVA 33/11 kV	750.797.640	49.743.114	2.387.669.479	3.188.210.233	4.171.098.000	982.887.767	17	838	25000	40000
21	X21	50 MVA 110/11 kV	2.407.570.155	153.225.552	7.354.826.511	9.915.622.218	13.375.389.750	3.459.767.532	33	1915	25000	40000
22	X22	50 MVA 17/63 kV	1.587.846.739	142.866.076	6.857.571.663	8.588.284.479	8.821.370.775	233.086.296	30	1896	25000	40000
23	X23	60 MVA 150/20 kV	1.625.489.280	118.878.105	5.706.149.019	7.450.516.404	9.030.496.000	1.579.979.596	23	1203	25000	40000
24	X24	60 MVA 150/22 kV	1.893.909.414	134.912.379	6.475.794.175	8.504.615.967	10.521.718.966	2.017.102.999	23	1244	25000	40000
25	X25	60 MVA 150/70 kV	1.734.594.906	133.180.555	6.392.666.637	8.260.442.098	9.636.638.368	1.376.196.270	27	1315	25000	40000
26	X26	80 MVA 150/20 kV	2.422.426.483	171.393.883	8.226.906.382	10.820.726.748	13.457.924.904	2.637.198.157	27	1413	25000	40000

The product requirements requested by consumers are obtained from the 12-month history data owned by the company, the data is then processed into the company's production target for the needs of the next 12 months. Forecasting production needs that are input into production planning is adjusted to the forecasting results that have been carried out by the company for the next 12 months which can be seen in table 3.

Table-3: Description of Research Variables

No	Variable	Description	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Grand Total
		Active days in Month	**18**	**20**	**16**	**21**	**22**	**19**	**22**	**22**	**18**	**22**	**19**	**21**	**240**
1	X1	10 MVA 110/11 kV							1						**1**
2	X2	10 MVA 33/11 kV				2									**2**
3	X3	100 MVA 150/66 kV										1			**1**
4	X4	100 MVA 150/70 kV					3	1	1			1	1		**7**
5	X5	100 MVA 150/70/10 kV								1					**1**
6	X6	120 MVA 220/114/11 kV									1				**1**
7	X7	135 MVA 150/20 kV								3					**3**
8	X8	167 MVA 500/150 kV	1		1	2	1	3	1	1	1	1	3		**15**
9	X9	20 MVA 33/11 kV					2					2			**4**
10	X10	20 MVA 33/66 kV						1							**1**
11	X11	215 MVA 150/11 kV										1			**1**
12	X12	23 MVA 66/11 kV							1						**1**
13	X13	24 MVA 33/11 kV						2							**2**
14	X14	250 MVA 220/110/11 kV									1				**1**
15	X15	30 MVA 150/20 kV					1		2	1					**4**

No	Variable	Description	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Grand Total
		Active days in Month	**18**	**20**	**16**	**21**	**22**	**19**	**22**	**22**	**18**	**22**	**19**	**21**	**240**
16	X16	30 MVA 150/22 kV						3		1	4	2	2	3	**15**
17	X17	30 MVA 66/22 kV											2		**2**
18	X18	30 MVA 66/23 kV								1					**1**
19	X19	30 MVA 70/22 kV	1									3		2	**6**
20	X20	5 MVA 33/11 kV										1			**1**
21	X21	50 MVA 110/11 kV												1	**1**
22	X22	50 MVA 17/63 kV								1					**1**
23	X23	60 MVA 150/20 kV	2	1											**3**
24	X24	60 MVA 150/22 kV		2	14	8	7	1	4	6	8	1	5	4	**60**
25	X25	60 MVA 150/70 kV	1		1				2						**4**
26	X26	80 MVA 150/20 kV										2			**2**
		Grand Total	**5**	**3**	**16**	**12**	**14**	**11**	**12**	**15**	**15**	**15**	**13**	**10**	**141**

Analysis of Research Results

Company data collected has been processed using mixed integer linear programming method with the help of lindo 6.1 software. In this data processing, a comparison of production planning strategies with alternative strategies of all available resources is the number of products, employee working hours, number of employees and the amount of inventory that will be compared with the current production planning strategy by using a fixed number of employees. Table 4. shows the results of data processing that have been carried out on PTAID resulting from Lindo 6.1 programming shows that alternative production planning strategies produce lower production costs compared to the current strategy of the company. A production cost decrease of 4.6% or Rp. 57,661,862,889, - from Rp. 1,249,002,284,528, - to Rp. 1,191,340,421,639, - for 12 months of planning time.

Table-4: Data Processing Results of PTAID

Item	Unit	Strategy		Gap
		Current Condition	Alternative	(Delta)
Total Cost	Rupiah	1.249.002.284.528	1.191.340.421.639	57.661.862.889
Output Product (Normal)	Unit	141	141	0
Output Product (Over time)	Unit	0	0	0
Stock product	Unit	0	56	56
Manhours (Normal)	Man Hours	201541	191594	9947
Manhours (Over time)	Man Hours	0	0	0
Man Power Total	Persons	173	173	0

Table 4 shows the results of data processing that has been carried out by Lindo 6.1 programming results that alternative production planning strategies produce lower production costs compared to the strategies that the company currently does. A production cost decrease of 4.6% or Rp. 57,661,862,889, - from Rp. 1,249,002,284,528, - to Rp. 1,191,340,421,639, - for 12 months of planning time.

It can be seen in Figure 2 that production costs are increasing along with the increase in the planning time period. This is because increased demand causes an increase in production costs. In the initial period of the month, the strategy applied by the company has a production cost that is slightly cheaper compared to alternative strategies. However, along with the increasing number of requests, alternative strategies produce lower production costs when compared to the current strategy implemented by the company, which has a decrease of 4.6% or Rp. 57,661,862,889, - the result of production costs.

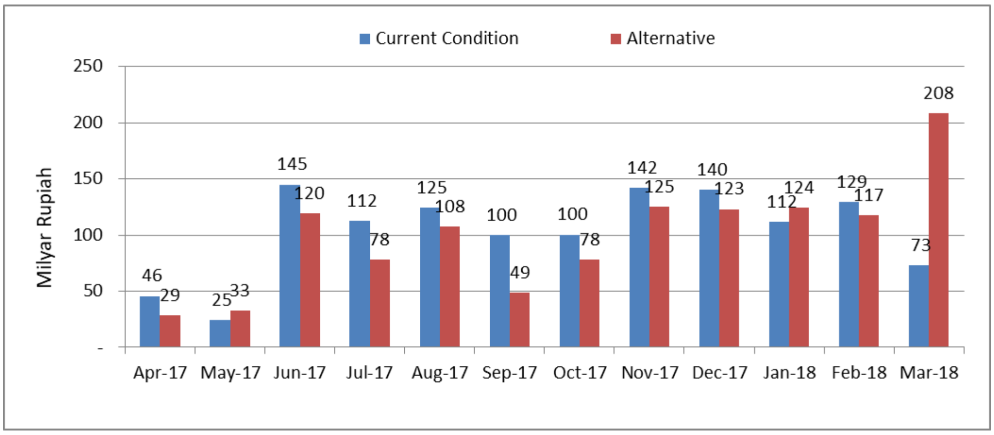

Fig-2: Total Production Cost of Transformers (Billions of Rupiah / Month)

Analysis of Total Production in Normal and Overtime Working Hours. One of the decision variables in this study is Xit and Yit. This variable shows the number of products produced during normal working hours which can be seen in Figure 3 and the amount of production during overtime hours can be seen in Figure 4.

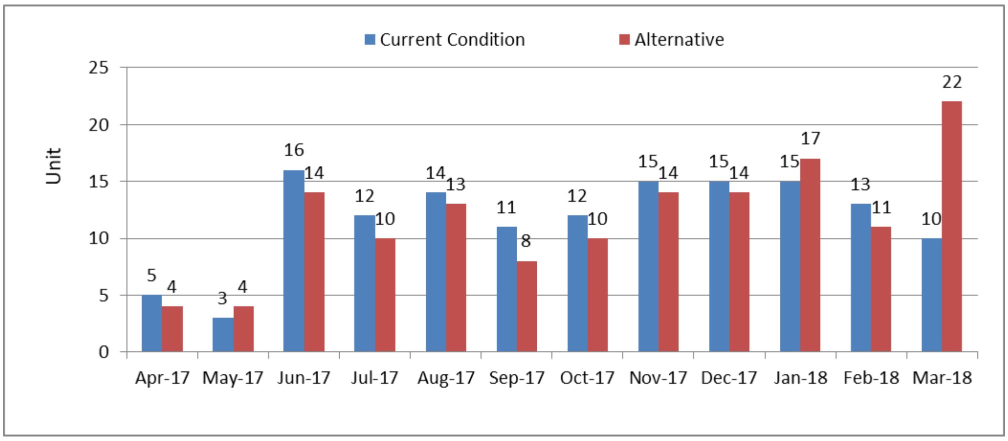

Fig-3: Total Production in Regular Business Hours (Unit / Month)

It can be seen in Figures 3 and 4, that by using alternative strategies can minimize production costs by increasing the amount of production during normal working hours and avoiding production in overtime, as seen in Figure 4 where the alternative strategy has no production at all overtime.

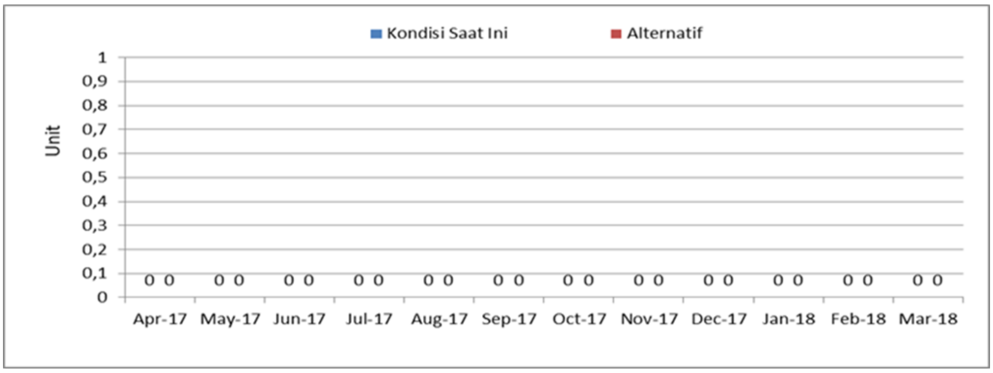

Fig-4: Total Production in Overtime Working Hours (Unit / Month)

This is because labor costs at regular work time are relatively lower compared to labor costs during overtime work. The alternative strategy has a greater amount of production at regular working time compared to production in the current strategy conditions used by the company, where the condition of the strategy has a total production of 141 units while the alternative strategy conditions have a fixed production amount of 141 units. Total production during regular work and overtime.

Analysis Needs of Number Normal and Overtime Working Hours. Alternative strategy planning maximizes the use of regular work hours because labor costs in regular working hours are relatively lower compared to overtime hours. It can be seen in Figures 5 and 6, that the aggregate planning strategy has a greater need for normal working hours compared to the strategies used by the company.

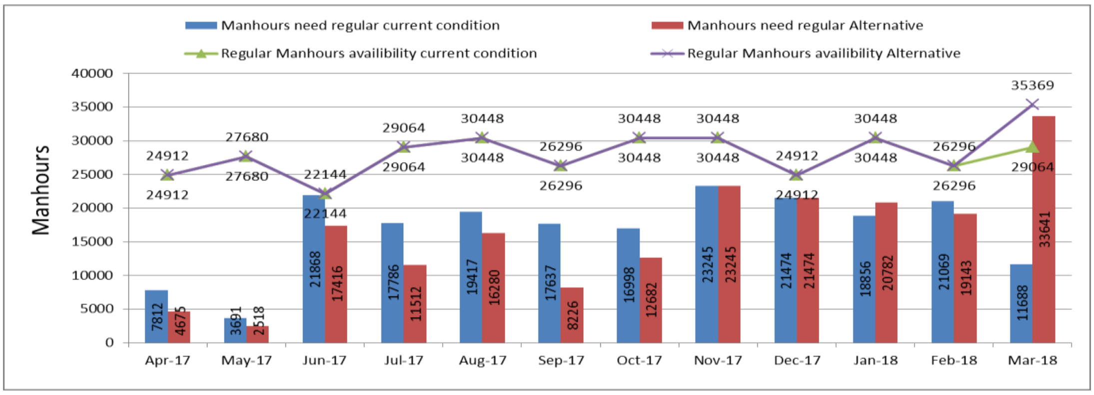

Fig-5: Requirements for the Number of Regular Working Hours (People / Month Hours)

While alternative strategies have flexibility in the use of employees. In Figure 6 it can be seen that in the final period of planning, the need for overtime working hours is stagnant. Even though customer demand has increased followed by the availability of regular working hours available, it is enough to keep running the process so that it does not increase the use of overtime hours.

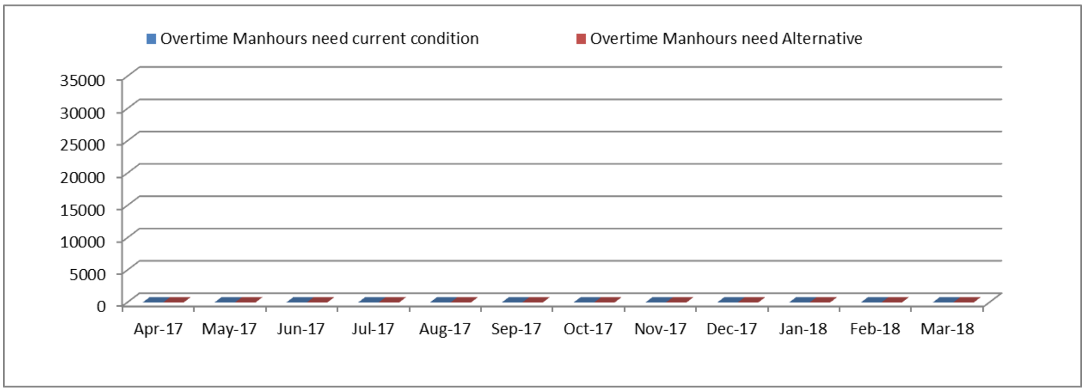

Fig-6: Requirements for Overtime Working Hours (Person / Month Hours)

In the condition of alternative strategies, as seen in Figure 6, when customer demand has increased, the availability of regular working hours owned by the company is sufficient to meet the needs of working hours for production, because the company has the flexibility to use employees, as many as 173 employees result in the availability of working hours regular can anticipate production needs so as to avoid the need for company overtime hours. Based on the above analysis, the strategy of the company at this time does not require additional overtime hours that are greater than the alternative strategy, which has an impact on the increase in the company's production costs.

Analysis of Total Goods Inventory

Inventory variables can anticipate the limited resources owned by the company. The availability of inventory is intended to help companies to meet customer demand with the availability of resources [5]. From the results of the model formulation that has been carried out in this study, the results obtained are as shown in Figure 7 below.

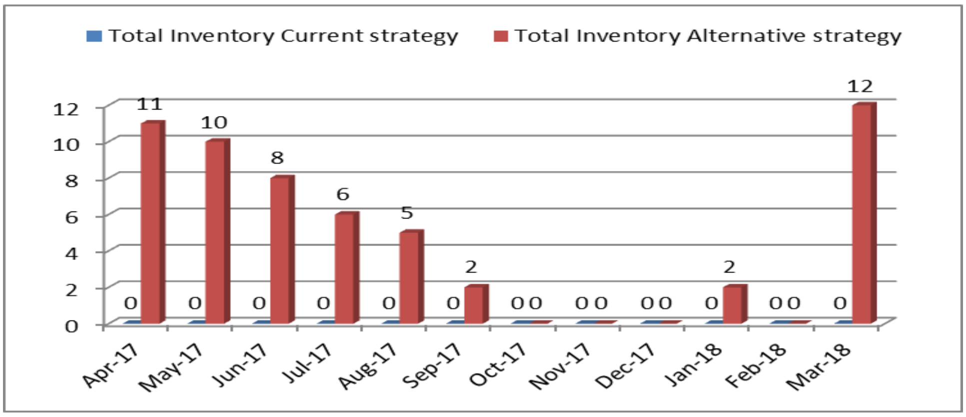

Fig-7: Number of Stored Inventories (units / months)

Figure 7 shows the amount of inventory stored by PTAID during the planning period. The red column is the amount of inventory stored under alternative strategy conditions. It can be seen in Figure 7 that the current condition of the company's strategy has inventory in the second to sixth month period. This is because during this period, the need for regular working hours is under the availability of regular working hours so that the amount of production during regular working hours can be increased to provide inventory in anticipation of the needs of the next period. Whereas after the seventh and eighth periods, the strategy carried out by the company does not have inventory because the need for regular working hours has reached the availability limit. Taking into account the cost of inventory and the cost of using overtime hours, in the ninth period until the end of the period there is no additional overtime work as shown in Figure 6. As for the alternative strategy conditions as shown in Figure 4, to avoid working hours overtime, the company maximizes the use of regular work hours to make inventory in anticipation of production needs in the next period.

Analysis of Number of Employees Use needed

In minimizing the production costs of PTAID Transformers, by processing data using LINDO 6.1 software, the results are not required to increase the number of employees in the next period so that the cost of employee expenses will remain.

Sensitivity Analysis

The results of the optimization obtained from a model, carried out a sensitivity analysis or sensitivity to changes in one or more of the parameters of the components of operational costs, labor, and inventory costs. This is intended to test the reliability of the system / model that has been made against the changes in the boundary.

Sensitivity Changes in Operational Cost Parameters for Optimal Solutions

Operational costs consist of packaging costs, transportation costs and overhead costs. Changes in operational costs will cause changes to the optimal solutions that are achieved as seen in table 5 below, where given an increase and decrease in operating costs to find out how it affects the optimal solutions obtained. It can be seen in table 5 that when operational costs have decreased by 10%, it will cause the optimal solution to change as much as 11.1% or experience changes as much as Rp. 119,134,042,163. This shows that PTAID must be prepared to anticipate the increase or decrease in operational costs of the total production costs obtained during the planning time.

Table-5: Changing Sensitivity of Operational Cost Parameters to Optimal Solutions

Adjust Paramter Operation Cost	Optimal Solution (Rupiah)	Change Cost (Rupiah)	Persent Change
-10%	1.072.206.379.475	-119.134.042.164	-11,11%
-5%	1.131.773.400.557	- 59.567.021.082	-5,26%
Fixed	1.191.340.421.639		0,00%
5%	1.250.907.442.721	59.567.021.082	4,76%
10%	1.310.474.463.802	119.134.042.164	10,00%

Sensitivity of Changing Demand Parameters to Optimal Solutions

Demand is forecasting customer requests during planning time. Table 6 shows how the effect of changes in the increase or decrease in demand for the optimal solution obtained.

Table-6: Sensitivity of Changing Demand Parameters to Optimal Solutions

Adjust Paramter Demand	Optimal Solution (Rupiah)	Change Cost (Rupiah)	Persent Change
-6%	1.119.859.996.340	-71480425298	-6,38%
-3%	1.155.600.208.989	-35740212649	-3,09%
Fixed	1.191.340.421.639		0,00%
3%	1.227.080.634.288	35740212649	2,91%
6%	1.262.820.846.937	71480425298	6,00%

Seen in table 6, that change in demand greatly affects the optimal solution that is obtained. When customer demand decreases or increases 6%, will affect the optimal solution total production costs obtained as much as 6.4% or as much as Rp. 71,480,425,298. This means that every change of 1% demand will have an impact on 1.06% of the total production costs of the Transformer. This shows that, this demand parameter is a parameter that is most vulnerable to the optimal solution that is obtained, so that the company must be able to anticipate this change in demand adjusted to the company's financial condition during the planning interval.

Managerial Implications

The first scenario is to use the strategy used by the company at present, namely by using a fixed number of employees. In this strategy, the company does not require the addition or reduction of employees so that the company does not need to do and issue training fees and termination of employment. However, in this strategy there is a weakness, namely if the demand for customer demand increases will cause an increase in employee overtime due to the limitations of regular time working hours (figure 4.14) so that overtime costs will increase. In addition, if demand is experiencing a phase of decline, it will cause waste of employee working hours. So that causes labor costs are not balanced with the condition of corporate income.

The second scenario is by using the strategy of flexibility to use the number of employees. In this strategy, the company tries to add or subtract employees according to customer demand, so that the company can balance the limited resources it has with the demand requirements. The use of this strategy can incur costs for recruitment and termination of employment. In addition, the company also needs time for new employees to adapt to their duties. The company has an additional number of employees due to limited infrastructure or production equipment owned. So that in this study the limitation of employee use is up to a maximum of 173 employees in accordance with the production equipment owned by the company. Regarding employee reductions, if this happens, it will have an impact on the psychology that employees have for their convenience in working at PTAID.

CONCLUSIONS

The results of the research that has been done, there are several conclusions that can be obtained, namely:

- The optimal amount of production (normal working hours and overtime) is 141 product units.
- The availability of normal working hours and overtime is 332.160 working hours then decreases with an optimization strategy from 201,541 hours of people to 193,755 hours of people or a decrease of 4%.
- The optimal amount of inventory is 67 units during the 12 months of planning.
- The optimal amount of workforce is fixed at 173 employees or, the company does not need to increase the number of their employees.
- With the existing production capacity optimization strategy for a 12-month planning period, then the minimum Transformer production costs at PTAID can be 4.6% or Rp. 57,661,862,889, - from Rp. 1,249,002,284,528, - to Rp. 1,191,340,421,639, -.

SUGGESTIONS

- Development of a formulation of the number of products being increased or lowered so that it knows the effect on all costs.
- The decline in working hours has only reached 4%, it is expected that in the next study can increase the decline in costs again to above 7%.
- The number of product inventories increases by 69 units and that is enough to accelerate the fulfillment of customer needs
- The reduction in costs has reached 4.6%, it is expected that in the next research can increase the cost reduction again to above 5%.
- Last advice for PTAID companies, in terms of operational considerations given that PTAID is a Transformer producer company which has a very high level of risk if there are no orders from customers. So it is advisable to use a flexible workforce with a work agreement so that it is easy to terminate the work relationship with the number of employees who are always optimal in every situation.

REFERENCES

1. Gansterer M. Aggregate planning and forecasting in make-to-order production systems. International Journal of Production Economics. 2015 Dec 1;170:521-8.
2. Chase RB, Jacobs FR & Aquilano NJ. *Operations Management for Competitive Advantage*. New York: McGraw-Hill/Irwin. 2006.
3. Siswanto. *Operations Research*. Bogor: Erlangga. 2006.
4. Buxey G. Aggregate planning for seasonal demand: reconciling theory with practice. International Journal of Operations & Production Management. 2005 Nov 1;25(11):1083-100.
5. Liu X, Tu Y. Production planning with limited inventory capacity and allowed stockout. International Journal of Production Economics. 2008 Jan 1;111(1):180-91.
6. Kumar S, A & Suresh N. *Production and Operations Management*. 2nd ed. New Delhi: New Age International (P) Limited. 2008.
7. Mirzapour Al-E-Hashem SM, Malekly H, Aryanezhad MB. A multi-objective robust optimization model for multi-product multi-site aggregate production planning in a supply chain under uncertainty. International Journal of Production Economics. 2011 Nov 1;134(1):28-42.
8. Takey FM, Mesquita MA. Aggregate Planning for a Large Food Manufacturer with High Seasonal Demand. Brazilian Journal of Operations & Production Management. 2006;3(1):05-20.