Optimization benefits analysis in production process of fabrication components

R Prasetyani[1,2], A Y Rafsanjani[1] and D Rimantho[1]

[1]Industrial Engineering Department, Pancasila University, Jakarta
[2]rini.prasetyani@univpancasila.ac.id

Abstract. The determination of an optimal number of product combinations is important. The main problem at part and service department in PT. United Tractors Pandu Engineering (shortened to PT.UTPE) Is the optimization of the combination of fabrication component products (known as Liner Plate) which influence to the profit that will be obtained by the company. Liner Plate is a fabrication component that serves as a protector of core structure for heavy duty attachment, such as HD Vessel, HD Bucket, HD Shovel, and HD Blade. The graph of liner plate sales from January to December 2016 has fluctuated and there is no direct conclusion about the optimization of production of such fabrication components. The optimal product combination can be achieved by calculating and plotting the amount of production output and input appropriately. The method that used in this study is linear programming methods with primal, dual, and sensitivity analysis using QM software for Windows to obtain optimal fabrication components. In the optimal combination of components, PT. UTPE provide the profit increase of Rp. 105,285,000.00 for a total of Rp. 3,046,525,000.00 per month and the production of a total combination of 71 units per unit variance per month. **Keywords:** Optimization, Fabrication Component, QM for Windows

1. Introduction

Mining is one of an important pillar of development in Indonesia. This sector has long been the main sector contributing to the cash inflow of the country. However, starting in 2011 to date, the sector is showing a downward trend. The price of mineral and coal mining commodities is declining and has not shown any signs of increasing. Indonesia as one of the countries rich in mining commodities also feels the impact. The impact of the declining mining trend also has an impact on the manufacturing industry and heavy equipment distributor, where the number of heavy-duty equipment sales decreased dramatically. PT. United Tractors Tbk, as the core company of PT. United Tractors Pandu Engineering throughout 2016 must make several revisions to its sales target. The original sales target was 4,494 units of heavy mining equipment, then revised to 3,800 units. The Company has decreased approximately 10% by year on year based on 2016 PT United Tractors Annual Report. Faced with these conditions, PT. United Tractors Pandu Engineering (PT UTPE), which focuses on manufacturing heavy equipment supporting units such as dump vessel, backhoe bucket, grader blade, semi-trailer, water tank, etc. to perform efficiency measures on all business lines.

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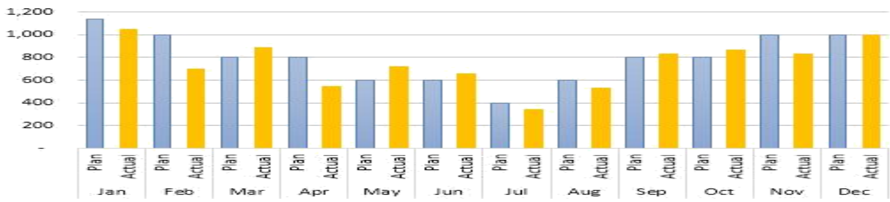

Figure 1. Plan and actual sales (total) fabrication component at PT. UTPE (million rupiahs)

The graph above shows the comparison of plans and actual sales of the fabrication components at PT. UTPE in million rupiahs during January to December 2016. Furthermore, the graph shows the value of fluctuating sales figures. Because of its fluctuating value, it cannot be concluded directly about the optimization of production of fabrication components in PT. UTPE just by looking at the graphs only. Based on these conditions, this paper will conduct further tests to determine whether the production of fabrication components at PT. UTPE is currently providing optimal benefits or not. The optimum benefits are influenced by the condition of factors affecting the production of the fabrication component, namely: production cost, raw materials, production hours, production equipment, and market demand. This study aims to analyze maximum profitable and the amount of optimum product combination.

2. Literature review

2.1. Optimization

Every company will try to achieve the optimal state by maximizing profits or by minimizing costs incurred in the production process. The company expects the best results with limited resources, in solving problems with optimization techniques to produce the best solution [1].

2.2. Linear Programming

Linear programming is a method of calculation for the best planning between possible actions that can be done. The best determination is that there are many alternatives in planning to achieve specific objectives on limited resources. The Linear program consists of two kinds of functions, namely the purpose function and function constraints. The purpose function is a function that describes the goal or goal in the sources to obtain maximum profit or minimum cost. While the constraint function is a mathematical representation of the available constraints that will be allocated optimally to various activities. In general, the linear programming model can be expressed as follows [3]:

- Function Objectives, maximizing or minimizing:
  $$Z = C_1X_1 + C_2X_2 + ... + C_nX_n \quad (1)$$
- Eligible Constraints
  $$a_{11}X_1 + a_{12}X_2 + ... + a_{1n}X_n \quad (=, \leq, \geq)\ b_1 \quad (2)$$
  $$a_{21}X_1 + a_{22}X_2 + \dots + a_{2n}X_n \quad (=, \leq, \geq)\ b_2 \quad (3)$$
  $$a_{m1}X_1 + a_{m2}X_2 + \dots + a_{mn}X_n \quad (=, \leq, \geq)\ b_m \quad (4)$$
  $$x_1, x_2, \dots, x_n \geq 0 \quad (5)$$

The limiting function can be either (=) or inequality (≤ or ≥). The limiting function is also called a constraint. Constants (both as coefficients and right values) in the constraint function and on the destination are said to be model parameters. The symbols x_1, x_2, ..., x_n (x_i) show the decision variables. The number of decision variables (x_i) therefore depends on the number of activities or activities undertaken to achieve the goal. The symbols C_1, C_2, ..., C_n are the contribution of each decision variable to the goal, also called the coefficient of the objective function in the mathematical model. The symbols a_{11}, ..., a_{1n}, ..., a_{mn} are the per unit use of the decision variable of the limiting resource, also called the functional constraint coefficient of the mathematical model. The symbols b_1, b_2, ..., b_m denote the number of each resource available. The number of constraint functions will depend on the limited number of resources. The last inequality (x_1, x_2, ..., $x_n \geq 0$) shows non-negative limits [3].

3. Result and discussion

3.1. Model Formulation

Formulation of the model in this research is to obtain the purpose function and constraint function. The purpose function of optimization of fabricated component products at PT. UTPE is maximizing profits or finding the difference between the selling price and the production cost. The costs include fixed costs and non-fixed costs. To find the value of decision variables in the form of profit on the purpose function (1) which has been described in Chapter III, the data used is the selling price and production cost of each product. The selling price, production cost, and net income of each fabrication component can be seen in the Table 1 below.

Table 1. Selling price, production cost, and net income of 2016

Product Type	Price (Rp/Unit)	Production Cost (Rp/Unit)	Profit (Rp/unit)
Liner plate dozer	84,460,000	67,031,740	17,428,260
Liner plate vessel	144,900,000	120,709,700	24,190,300
Liner bucket PC 4000	344,900,000	265,307,700	79,592,300
Liner bucket PC 2000	299,500,000	233,984,375	65,515,625
Liner bucket PC 1800	199,880,000	156,156,250	43,723,750

The coefficient on the purpose function (1) is the net income (profit) per unit of each type of fabrication product obtain from the sale. After the input parameters for each product is known then the purpose function to maximize the profit can be formulated as follows:

$$\text{Maximize } Z = 17{,}428{,}260X_1 + 24{,}190{,}300X_2 + 79{,}592{,}300X_3 + 65{,}515{,}625X_4 + 43{,}723{,}750X_5 \quad (6)$$

3.2. Formulation of constraining function

Several obstacles that often occur in the production process, especially in manufacturing fabrication components at PT. United Tractors Pandu Engineering consists of: production cost constraints, raw material constraints, production hours constraints, time constraints on the use of production equipment, and market demand constraints.

3.2.1. Cost production constraint. The availability of financial capital is a way of allocating the average capital available to commercialize each type of fabrication product. The availability of working capital for fabrication component business in PT.UTPE monthly average of 2016 is Rp. 11,470,231,000. The constraint function for production costs based on Table 1 can be formulated below:

$$67{,}031{,}740X_1 + 120{,}709{,}700X_2 + 265{,}307{,}700X_3 + 233{,}984{,}375X_4 + 156{,}156{,}250X_5 \leq 11{,}470{,}231{,}000 \quad (7)$$

3.2.2. Raw material constraint. In the formulation of the function of raw material constraint coefficient function of raw material, the constraint is the amount of raw material per unit of product. In addition, the amount of raw material availability per month is shown on the right value of the raw material constraint function. Raw materials used in producing fabrication components at PT. UTPE is a sheet iron with a grade of Hardox grade 400. The amount of iron sheeting is a factor to be considered. The constraints on the sheet iron of each sheet per unit are obtained from data provided by the production department of PT. UTPE is 300 sheets/month. Based on the data of the amount of iron usage, the formulation of the iron sheet raw material constraint function in manufacturing the fabrication component is as follows:

$$3X_1 + 2X_2 + 8X_3 + 5X_4 + 4X_5 \leq 300 \quad (8)$$

3.2.3. Production hour constraint. Production workforce is a person who contributes to assisting the production process in turning raw materials into finished materials. In the production process, the fabrication component has a total of 10 persons of production labor, the number of working hours is 6 hours/day, and the number of working days is 22 days in one month. From the data obtained, it is known that the availability of labor production time per month is 1320 hours/month. Based on the 2016 monthly average labour data, the formulation of the constraint function of production working hours in the manufacture of fabrication components are as follows:

$$12X_1 + 10X_2 + 24X_3 + 18X_4 + 13X_5 \leq 1320 \quad (9)$$

3.2.4. Production equipment usage constraints. The constraints of production equipment are calculated based on the amount of time available for an apparatus to produce a product. This is influenced by the number of working hours available. The units used to know the constraints of production equipment are hours/units. PT. UTPE in running its business using production equipment namely Plasma Cutting Machine, Big blue Air pack Welding Machine, and Crane. The production equipment is used to perform the production process on each type of fabrication component.

Plasma cutting machine is used to assist the manufacturing process of fabrication components especially in producing pieces of iron sheets (liner plate) according to the design made. The availability of plasma cutting machine working hours at PT.UTPE is 420 hours/month. This result is obtained from multiplication of available plasma cutting machine 3 units with production time 7 hours/day, and a number of working days 5 days/week and 4 weeks in a month. Based on the 2016 monthly average data of cutting time, the formulation of time constraint function of plasma cutting machine in making of fabrication component is as follows:

$$4X_1 + 4X_2 + 8X_3 + 6X_4 + 5X_5 \leq 420 \quad (10)$$

Welding machine big blue air pack is used to assist the welding process between liner plates after cutting. Availability of welding machine big blue air pack at PT. UTPE 540 hours/month. This result is obtained from the multiplication of the Number of Welding Machine Big blue Air pack available 3 units with production time 9 hours/day, and the number of working days 5 days/week for 4 weeks in 1 month. Based on monthly welding time, formulation of time constraint function of welding machine big blue air pack in the manufacture of fabrication component is as follows:

$$6X_1 + 5X_2 + 10X_3 + 8X_4 + 8X_5 \leq 540 \quad (11)$$

Crane is used to assist the process of moving or changing the position of the liner plate from post 1 to the next post. Crane clock availability at PT. UTPE is 280 hours/month. This result is obtained from the multiplication of the Number of cranes available is 2 units with production time 7 hours/day, and the number of working days 5 days/week for 4 weeks in 1 month. Based on the monthly crane usage time data, the formulation of crane availability constraint function in manufacturing fabrication component is as follows:

$$X_1 + X_2 + 5X_3 + 3X_4 + 3X_5 \leq 280 \quad (12)$$

3.2.5. Market demand constraints. Market demand constraints are used to determine the minimum constraints and the maximum limitations of production that must be generated. Demand is a number of goods consumers want to buy. The amount consumers want to buy is not always the same as the number actually purchased by consumers. The amount consumers want to buy is called a potential demand, while the amount actually purchased by consumers is called actual demand. Therefore, the potential demand is a demand that has not been followed by purchasing power, while the actual demand is demand followed by purchasing power. Potential demand is greater than real demand but can be equally large. Market demand constraints are used to determine the minimum and maximum limitations that PT.UTPE must produce to meet the market demand.

The constraints of market demand referred to in this constraint function are actual sales based on company data. The data is obtained from the total units that have been sold and operate the field that can be referred to as total demand. From the total demand available, sales potential can be determined by referring to the market share. The size of market share, influenced by several factors such as price, product quality, after-sales service, etc. The formulation of monthly market demand constraint function is formulated as follows:

$$X_1 \leq 10$$
$$X_2 \leq 10$$
$$X_3 \leq 18$$
$$X_4 \leq 10$$
$$X_5 \leq 10 \quad (13)$$

3.3. Primal Analysis
In the formulation of the optimization model, the expected results are the optimal results that can be achieved by the company in accordance with the objectives and constraints that become the limit in the production. Based on data processing with Microsoft Office Excel program and POM QM has been known optimal analysis results. The optimal results show optimal solutions consisting of optimal product combinations, optimal resource status, and sensitivity analysis.

From the results of the targeted product fabrication analysis set by PT. UTPE earned a profit of Rp 2,941,240,000 per month with the production of a total combination of 58 unit/month unit variants, consisting of 10 units of X1 components, X2 of 10 units, X3 of 18 units, X4 of 10 units and X5 of 10 units.

Table 2. The Use of resources at PT. United Tractors Pandu Engineering

Product Type	Availability	Optimal usage	Slack/surplus
Production Cost	11,470,240,000	10,554,360,000	915,881,000
Sheet steel	300	284	16
Man hour (hour)	1,320	962	358
Time usage for plasma cutting machine (hour)	420	334	86
Time usage for welding machine (hour)	540	450	90
Time usage for crane (hour)	280	190	90

3.3.1. Raw materials usage analysis. The raw materials that become a constrain in this study was an iron sheet of Hardox 400. In Table 2 it can be seen that the use of sheet metal has slack/surplus value of 16 sheets/month. This indicates that the sheet iron used is still excessive during the production process which means that the use of sheet iron is not yet optimal.

3.3.2. Labor time usage analysis. Based on the optimum results in Table 2, the use of production labor time has an overtime time of 358 hours which means the use of labor time of this production is not yet optimal. Under optimal conditions, the production workforce used is 962 hours from the availability of 1,320 hours.

3.3.3. Production equipment usage analysis. Production equipment that becomes an obstacle in this research is time constraint of using plasma cutting machine, welding machine big blue air pack, and crane. There is an excess time of use of production equipment which means not optimal when the use of production equipment. In the use of plasma cutting machine has an excess time of 86 hours/month with optimal use of 334 hours/month from the availability of 420 hours/month. Use on welding machine big blue air pack 450 hours/month from the availability of 540 hours/month and has an excess time of 90 hours/month. Similarly, the use of cranes during the production process has a usage time of 190 hours/month from the availability of 280 hours/month and has an overtime of 90 hours/month.

3.4 The Dual Analysis
The dual analysis is done to determine the assessment of resources by looking at the value of slack/surplus and its dual value. The value of slack/surplus is also related to the magnitude of the effect

of adding or decreasing the number of resources available and the results can be used for management decision-making. Analysis of the status of these resources can be seen in the Table 3 below.

Table 3. Analysis of resource status at PT. UTPE

Constraint	Dual Value	Slack/surplus	Original Val	Lower Bound	Upper Bound
Production Cost[a]	0	915.88	11,470.240	10,554.36	Infinity
Raw material	0	16	300	284	Infinity
Man hour	0	358	1,320	962	Infinity
Time usage for machine PC	0	86	420	334	Infinity
Time usage for machine WM	0	90	540	450	Infinity
Time usage for machine CN	0	90	280	190	Infinity
Total Demand X1	17,428,260	0	10	0	15
Total Demand X2	24,190,300	0	18	0	18
Total Demand X3	79,592,300	0	10	0	20
Total Demand X4	65,515,620	0	10	O	13
Total Demand X5	43,723,750	0	10	0	14

[a] = in million

Table 3 above provides information related the available resources are still excessive. Excess resources have dual value = 0 and slack/surplus value> 0, this indicates that there is no deficiency in the use of raw material business capital, labor time, and time of equipment during the production process of fabrication component at PT. UTPE. Thus, there is no limit on the availability of raw materials.

3.5. Sensitivity Analysis

Sensitivity analysis is performed to find out how far the answer of an optimal solution can be applied if there is a change in the model. This analysis shows the lapse of changes in the amount of resource availability that does not cause the change in the value of the dual constraints concerned. The hose also indicates the importance of a resource, where the smaller the hose the more important the resources are of the condition. The sensitivity interval is indicated by the minimum and maximum value of the allowable inventory. Table of sensitivity analysis for business capital resources, raw materials in the form of an iron sheet, labor time, and machine usage time is as the Table 4 below.

Table 4. Analysis of resource sensitivity at PT. UTPE

Constraint	Dual Value	Slack/surplus	Original Val	Lower Bound	Upper Bound
Production Cost[a]	0	915.88	11,470.240	10,554.36	Infinity
Raw material	0	16	300	284	Infinity
Man hour	0	358	1,320	962	Infinity
Time usage for machine PC	0	86	420	334	Infinity
Time usage for machine WM	0	90	540	450	Infinity
Time usage for machine CN	0	90	280	190	Infinity
Total Demand X1	17,428,260	0	10	0	15
Total Demand X2	24,190,300	0	18	0	18
Total Demand X3	79,592,300	0	10	0	20
Total Demand X4	65,515,620	0	10	O	13
Total Demand X5	43,723,750	0	10	0	14

[a] = in million

From Table 4 above it can be seen that the status of excess resources. Thus, that if resources such as business capital, raw materials, labor time, machine usage time are reduced as much as allowed in accordance with the minimum limit in Table 4 then it will still get the optimal benefit. This is because the available resources have advantages over the intended use of the fabrication component manufacturing process. In addition, the availability of venture capital, raw materials, labor time of production, machine usage time has an infinite increase (infinity), it is because the optimal conditions are achieved resources that are not used up so that the addition of resources will not affect the value of the dual and does not change its optimum production. By knowing at the minimum value and maximum limits of each resource constraint function, the management of PT. United Tractors Pandu Engineering may obtain information in making adjustments to the procurement of resources.

3.6. Verify Combination Targets

Based on the results of optimization and analysis that has been done, it can be concluded that the target combination of production of fabrication components that is determined by the company has not been optimal. Under these conditions, the study re-tested the combination of products, by increasing the number of market demand and without changing the function of objectives and the availability of venture capital, raw materials, labor time, and time of use of existing machinery. The optimum iteration table with customized market demand constraints is shown below:

Table 5. Optimal iteration with an increase in the number of market demand

Constraint	X1	X2	X3	X4	X5	RHS	Dual
Maximize[a]	17.42	24.19	7.96	65.51	43.72		
Production cost[a]	67.03	120.71	265.31	233.99	156.15	11.47	0
Raw material	3	2	8	5	4	300	0
Man hour	12	10	24	18	13	1,320	0
Time usage for machine PC	4	4	8	6	5	420	0
Time usage for machine WM	6	5	10	8	0	540	0
Time usage for machine CN	1	1	5	3	5	280	0
Total Demand X1	1	0	0	0	0	13	17,426,260
Total Demand X2	0	1	0	0	0	22	24,190,300
Total Demand X3	0	0	1	0	0	12	79,592,300
Total Demand X4	0	0	0	1	0	13	65,515,620
Total Demand X5	0	0	0	0	1	11	43,723,750
Solution	13	22	12	13	11	3,046,520,000	

[a] = in million

Table 6. Analysis of resource sensitivity at PT. UTPE with increasing market demand:

Variable	Value	Reduced	Original	Lower	Upper
X1	13	0	17,428,260	0	Infinity
X2	22	0	24,190,300	0	Infinity
X3	12	0	79,592,300	0	Infinity
X4	13	0	65,515,620	0	Infinity
X5	11	0	43,723,750	0	Infinity
Constraint	Dual	Slack	Original	Lower	Upper
Production cost[a]	0	0	11,470.24	11,470.23	Infinity
Raw Material	0	12	300	288	Infinity
Man hour	0	279	1,320	1,041	Infinity
Time usage for machine PC	0	51	420	369	Infinity
Time usage for machine WM	0	40	540	500	Infinity
Time usage for machine CN	0	91	280	189	Infinity
Total Demand X1	17,428,260	0	13	0	13
Total Demand X2	24,190,300	0	22	0	22
Total Demand X3	79,592,300	0	12	0	12
Total Demand X4	65,515,620	0	13	O	13
Total Demand X5	43,723,750	0	11	0	11

[a] = in million

From the Table 5 above, after an increase in the number of market demand then PT. UTPE earns a profit of Rp 3,046,525,000 per month (profit increase of Rp 105,285,000) with the production of a total combination of 71 units per unit variance, consisting of X1 = 13 units, X2 = 22 unit, X3 = 12 units, X4

= 13 units and X5 = 11 units. From the combination result if continued with the primal-dual analysis and sensitivity analysis, then the condition as illustrated in the Table 5 above.

In Table 6 it can be seen that the use of production cost is optimal, it is because of the value of slack/surplus = 0 besides the value for the upper limit of the number of requests X_1, X_2 ..., X_5 is equal to the original value, which is optimal. But there are still excess resources, although there is a decrease in the amount of raw material with the initial value of 16 drops to 12, the labor time with the initial value of 358 drops to 279, the machine usage time A with initial value 86 drops to 51, with an initial value of 90 down to 40, and an increase in value at the time of use of machine C with an initial value of 90 rising to 91. With the end result, the combination of fabrication components that have increased the number of market demand can be concluded close to optimal.

4. Conclusion

From the study conducted can be summed up that the results shows that the target combination of fabrication component products set by the management of PT. United Tractors Pandu Engineering currently could earns a maximum profit of Rp 2,941,240,000 per month, with 10 unit monthly production of Liner Plate Dozer, Liner Plate Vessel, Liner Plate Bucket PC 2000, and Liner Plate Bucket PC 1800.

Based on the analysis conducted, the result depict that the sheet iron used is still over 12 sheets/month, production labor time has an overtime time of 279 hours/month. The usage of plasma cutting machine has 51 hours/month, the wicking machine big blue air pack has 40 hours/month, and the use of crane has 91 hours /month which all of them stood under capacity.

The result of production optimization model shows that the company will gain maximum profit at Rp 3,046,525,000, - per month which has to produce monthly 13 units of Liner Plate Dozer, 22 units of Liner Plate Vessel, 12 units of Liner Plate Bucket PC 4000, 13 units of Liner Plate Bucket PC 2000, and 11 units of Liner Plate Bucket PC 1800.

5. References

[1] Herjanto E 2008 *Manajemen Operasi Edisi Ketiga* (Jakarta :Grasindo)
[2] Mulyono S 2007 *Riset Operasi* (Jakarta: Fakultas Ekonomi Universitas Indonesia)
[3] Nasendi B D E and Anwar *Program Linear dan Variasinya* (Jakarta: Gramedia)
[4] Wahyuni T and Nuharini D 2008 *Matematika Konsep dan Aplikasinya* (Surakarta: Departemen Pendidikan Nasional)
[5] Handoko T H 1999 *Dasar-dasar Manajemen Produksi dan Operasi* (Yogyakarta: BPFE)