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Optimization of Vehicle Polish Liquid Production Quantity at Son Polish Using Integer Programming

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ABSTRACT
Son Polish is an industry that produces various liquid products that are useful for caring for the body and components in automotive vehicles. Although it has been established for a long time, Son Polish will only undergo the acquisition process for the first time in 2025. So that in its implementation, Son Polish does not have a production management system in determining the optimal daily production output by considering the capacity of the company's resources. Considering that Son Polish currently has 8 types of products, each of which has different resource needs, of course. This condition causes a deviation that occurs between the amount of production and consumer demand who have various types of products. Therefore, the purpose of this study is to determine the optimal combination of production amounts. Based on the results of the integer programming model using the branch and bound method which was completed using lingo software, a combination of Son Polish production was obtained by producing 3 batches of Son Spray, 2 batches of Son Jelly, 1 batch of Son Taro, 2 batches of Tire Polish, 2 batches of Son Black, 1 batch of Son R, 1 batch of Haalus Compound and 1 batch of Rough Compound. With a profit obtained of Rp. 136,365,000.00/month or equivalent to Rp. 5,454,600.00/day.

INTRODUCTION

The development of the developing automotive industry has also encouraged the creation of an industry engaged in automotive vehicle maintenance. One of them is the Son Polish industry which has been established since 1997 and in 2025 precisely in March Son Polish has just experienced a transfer of ownership for the first time. Son Polish is an industry engaged in the production of automotive vehicle maintenance fluids. Currently, the Son Polish industry has produced 8 types of motor vehicle maintenance products, including Son Spray, Son Jelly, Son Talas, Tire Polish, Son Black, Son R, Rough Compound and Fine Compound.

With 8 types of products owned by the company, Son Polish faces fluctuating demand so that there are irregularities in meeting market demand. Although there are products that are able to be fulfilled, there are products that are not able to be fulfilled and even experience overproduction. This condition illustrates that the production planning of Son polish has not been running optimally. This is because Son Polish does not have a well-structured production plan, especially in the allocation of company resources. So that the company's resources are not evenly distributed to the 8 products owned by Son Polish. Considering that Son Polish has just experienced a transfer of ownership which also

contributes to Son Polish's management system, especially in production planning, it has not been really well arranged.

Production planning is one of the important aspects for the industry to create efficient and effective conditions in the implementation of its operations. According to [1] production planning is the process of ensuring that the products produced are in accordance with what has been determined, including determining the production needed. So, it can be said that production planning is also a very important corporate management function, especially in determining the optimal product by considering the resources owned by the company. Effective and efficient production planning certainly involves market demand, production capacity and resources owned by the company [2]. Product optimization is the process of using optimal resources, which has an influence on the profits that will be obtained [3].

Through the urine of problems faced by Son Polish, this research aims to carry out production planning by determining the optimal combination of the number of Son Polish products based on the resources owned by Son Polish. Production optimization is defined as optimizing the available resources so as to produce the expected amount, of products in achieving the company's goals [4]. Resources are components that have an important role in determining the success of the production process [3]. The resources referred to here include, capital, labor, time, raw materials, and other supporting facilities such as production machinery. In determining the optimal production combination, this study uses an operations research model approach, namely linear programming.

According to [5] in managing production efficiently, operations research can be an answer, because operations research has a mathematical method to optimize the use of resources. Research is defined as an organized process of determining the truth of a problem, while operation is an action that is applied to several problems [6]. Operations research is an application consisting of a set of techniques, methods, and scientific tools used in dealing with problems that arise in the company [7] Linear programming is one of the mathematical methods in operations research that is often used in managerial decision-making [6].

The use of linear programming in company decision-making is the allocation of resources so that profits will be maximum or alternatively minimum costs [7]. However, the products produced by Son Polish have units/pcs that require the result of the decision variable in the form of an integer. Downward [8], in overcoming the problem of optimal results that must have integers, integer programming can be used that can convert fractional numbers into integers (integers).

The method used in the integer model in obtaining the result of integer value decision variables is by using the branch and bound method. Branch and bound is a method developed from a linear program in which some or all of the variables are required to have an integer value [9]. In this study, software lingo is also used as a tool to complete the integer programming optimization model. According to [9], software lingo is a software that is commonly used in solving optimization cases to avoid errors in manual completion. Therefore, this study will later determine the optimal combination of production amounts in each Son Polish product, through an integer programming model that has the purpose of maximizing the company's profits by using the limits of Son Polish's resources.

MATERIALS AND METHODS

Research Location

In the study "Optimizing the Production of Motorcycle Polishing Fluid in Son Polish Using the Integer Programming Approach" was carried out on a Son Polish home industry. Son Polish is one of the home industries engaged in producing liquids that function to treat the interior/exterior components of automotive vehicles. Son Polish Industry is located in Tanggulangin District, Sidoarjo Regency, East Java.

Data collection

In conducting the research, the author conducted direct observations in the field to collect the necessary data. The data collection technique in this study was by conducting interviews with the owners and employees of Son Polish production. In addition, the researcher also measured working time to obtain the standard time of each workstation on each Son Polish product using a stopwatch. In the production process, all products have the same production process flow, starting from compounding & mixing raw materials, labelling, filling, sealing, to the packing process. The production system implemented by Son Polish is the batching system, where in one production cycle Son Polish produces a certain amount based on the type of product produced. The following are the results of the data that has been collected:

Table 1. Sales Profit Data for Each Son Polish Product Per Batch

Product	Batch (Pcs)	Selling Price/Batch	Profit/Batch
Son Spray	120	Rp. 720,000	Rp. 216,000
Son Jelly	56	Rp. 616,000	Rp184,800
Son Talas	120	Rp. 1,800,000	Rp. 540,000
Tire Polish	56	Rp. 700,000	Rp. 210,000
Son Black	100	Rp. 2,000,000	Rp. 600,000
Son R	150	Rp. 2,550,000	Rp. 765,000
Compound Kasar	480	Rp. 2,400,000	Rp. 720,000
Compound Halus	480	Rp. 2,640,000	Rp. 792,000

Table 2. Standard Time for Each Work Station on Each Son Polish Product and Shrink Packing Machine

Workstation / Product	Raw Material Mixing and Formulation	Labeling	Shrink Packing	Filling	Sagelling	Packing
	Standard Time	Standard Time		Standard Time	Standard Time	Standard Time
Son Spray	1259.14	8.18	10.84	14.91	4.89	18.45
Son Jelly	1367.55	9.83	-	11.46	10.19	-
Son Talas	1223.91	7.55	-	20.68	18.53	18.16
Tire Polish	1375.58	9.96	-	11.49	11.30	-
Son Black	1428.70	7.66	-	21.16	12.65	10.46
Son R	1559.99	7.60	-	20.53	12.31	10.41
Compound Kasar	1522.54	7.11	-	7.64	9.08	18.35
Compound Halus	1946.86	7.32	-	7.53	8.95	18.77

Table 3. Standard Time for Each Work Station on Each Son Polish Product and Shrink Packing

Daily Raw Material Capacity			
Raw Material	Quantity	Raw Material	Quantity
Clear	750 liters	G1	15 liters
Clear Original	510 liters	P1	5 liters
Clear X	50 liters	P 809	80 Kilogram
Clear 10	15 liters	S1	10 Kilogram
Clear 14	50 liters	SR	10 Kilogram
Clear 20	25 liters	SR 4	7.5 liters
Powder	150 Kilogram	TW	50 milliliters
B9	10 liters	W1	2,000 liters
C1	15 Kilogram	W2	500 grams
C2	15 Kilogram		

Table 4. Product Composition – Son Spray, Son Jelly, and Son Talas

Son Spray		Son Jelly		Son Talas	
Raw Material	Raw Material	Raw Material	Raw Material	Raw Material	Raw Material
W1	34 L	W1	34 L	P1	5 L
P 809	120 l	P 809	250 mL	TW	250 mL
Clear	5 L	Clear	5 L	G1	60 ml
Clear 20	50 mL	Clear Ori	2 L	Clear	25 mL
W2	7 g	Clear 20	50 mL	W1	7 L
		W2	7 g		

Table 5. Product Composition – Semir Ban, Son Black, and Son R

Semir Ban		Son Black		Son R Super	
Raw Material	Raw Material	Raw Material	Raw Material	Raw Material	Raw Material
W1	32 l	SR	1 kg	Clear x	3 L
P 809	250 mL	SR 4	200 mL	Clear 14	1 L
Clear Ori	8 L	Clear	100 mL	B9	1 L
G1	1 L	Clear 20	40 mL	Clear 20	40 mL
Clear 20	70 mL				
W2	7 g				

Table 6. Product Composition – Compound Kasar & Compound Halus

Compound Kasar		Compound Halus	
Raw Material	Raw Material	Raw Material	Raw Material
Clear 10	2,5 L	Clear 10	2,5 L
Clear	7 L	Clear	6,5 L
G1	900 mL	Powder	8 kg
Clear 20	100 mL	S1	150 g
P 809	32 g	Clear 20	100 mL

Powder	8 kg	P809	32 g
S1	150 g		
C1	300 g		
C2	700 g		

Table 7. Product Composition - Son Polish Products

Product	Highest Demand (Batch)	Batch Quantity/Daily
Son Spray	55	3
Son Jelly	50	2
Son Talas	20	1
Polish	45	2
Son Black	40	2
Son R	10	1
Compound Kasar	25	1
Compound Halus	15	1

Method

According to [6], operations research has benefits in dealing with problems by coordinating operations or activities with existing limitations through the completion of "search for optimality". One of the methods contained in operations research is linear programming and integer programming. Linear programming is a tool used in solving with the aim of optimization [10]. The problem of optimizing company resources can be solved by a linear program approach (linear programming), namely by maximizing or minimizing the function of the goal [11]. Meanwhile, integer programming is one of the mathematical models of linear programs that has the additional requirement that all or some variables have non-negative values but the optimal number of solutions get a round value [12]. In solving using the integer programming model, the most commonly used method is the branch and bound method [13]. This branch and bound method is a method that limits the optimal adjustment that produces fractional numbers by making downward branching for each decision variable with a fractional value to produce an integer [12]. So .it can be said that in this study, it is solved with a mixture of both linear and integer models in determining the optimal combination of Son Polish production. The mathematical models used in the integer programming model are as follows [7]:

Objective Function:

$$Z = \sum C_j . X_j = C_1X_1 + C_2X_2 + \ldots + C_nX_n$$

Limitations or constraints:

$$\sum_{I=1}^{n} a_{ij}X_j \ (\leq = \geq) b_i \text{ for all i values } (i = 1,2, \ldots m)$$

Or

$$\begin{aligned} a_{11}X_1 + a_{12}X_2 + \ \ldots + a_nX_n(\leq = \geq)b_1 \\ a_{21}X_1 + a_{22}X_2 + \ \ldots + a_nX_n(\leq = \geq)b_2 \\ . \\ . \\ m.a_{m1}X_1 + a_{m2}X_2 + \ \ldots + a_{mn}X_{mn}(\leq = \geq)b_m \end{aligned}$$

To make the linear programming model produce integers, an integer limit is added to the mathematical model as follows [14]:

$$x_j \geq 0, \text{integer untuk setiap } x_j$$

Or

$$x_j \in \text{integer}$$

In formulating the mathematical model above, the steps are as follows:

1. Determine the benefits of each Son Polish product as a function of the purpose.
2. Making the capacity of working hours, raw materials/days and the highest demand for the period of July 2025 – December 2025 as the limit constraints.
3. Make the standard time of each workstation on each product as a coefficient at the limit of the capacity constraint of working hours. As well as the composition of each product at the limit of raw material capacity constraints.

From the mathematical model that has been formulated, then define each model in the software lingo to obtain the results of the decision variables from the integer programming model that has been created. According to [15], the lingo program provides an integrated package that includes a powerful language for interpreting optimization models, with complete work features for building and editing problems, as well as a set of built-in solvers capable of solving problems of various optimization models effectively and efficiently.

RESULTS AND DISCUSSIONS

Results

Mathematical Model

Integer programming in this research is carried out to determine the optimal combination of the number of products that can be produced by Son Polish by considering the resources owned by Son Polish. The steps in formulating the integer programming model in this study are as follows:

1. Determining Decision Variables
   Decision variables:
   x1 = Number of Son Spray Batches produced by Son Polish
   x2 = Number of Son Jelly Batches produced by Son Polish
   x3 = Number of Son Talas Batches produced by Son Polish
   x4 = Number of Tire Polish Batches produced by Son Polish
   x5 = Number of Son Black Batches produced by Son Polish
   x6 = Number of Son R Batches produced by Son Polish
   x7 = Number of Batches of Compound Kasar produced by Son Polish
   x8 = Number of Compound Batches Halus produced by Son Polish
2. Determining the Objective Function
   In this case, the objective function is formulated to determine the optimal quantity by maximizing profits based on the price of each product.
   Objective Function:
   Max Z = 216000x1 + 184000x2 +540000x3+210000x4+600000x5
   + 765000x6+720000x7+792000x8
3. Formulating Constraint Functions
   Constraint Function:
   a. Shrink Packing Machine Constraints
      $1301x1 \leq 28800$
   b. Work station working hour capacity constraints
      1) Mixing & mixing of raw materials

1259x1 + 1368x2 + 1224x3 + 1376x4 + 1429x5 + 1560x6 + 1523x7 + 1947x8 ≤ 28800

2) Labeling
982x1 + 550x2 + 906x3 + 558x4 + 766x5 + 1141x6 + 3415x7 + 3516x8 ≤ 28800
3) Charging
1789x1 + 642x2 + 2481x3 + 644x4 + 2116x5 + 3079x6 + 3667x7 + 3617x8 ≤ 28800
4) Sagelling
586x1 + 571x2 + 2223x3 + 633x4 + 1265x5 + 1846x6 + 4359x7 + 4298x8 ≤ 28800
5) Packing
184x1 + 182x3 + 1046x5 +1562x6 + 367x7+ 367x8 ≤ 28800

c. Raw material capacity constraints
1) Clear
5x1+5x2+0.025x3+0.1x5+7x7+6.5x8 ≤750
2) Clear Original
2x2+8x4 ≤510
3) Clear X
3x6 ≤10
4) Clear 10
2.5x7+2.5x8 ≤15
5) Clear 14
x6 ≤25
6) Clear 20
0.05x1+0.05x2+0.07x4+0.04x5+0.04x6+0.1x7+0.1x8 ≤1
7) Powder
8x7+8x8 ≤128
8) B9
x6 ≤8
9) C1
0.3x7 ≤2.4
10) C2
0.7x7 ≤5.6
11) G1
0.06x3+x4+0.9x7 ≤15
12) P1
5x3 ≤20
13) P 809
0.12x1+0.25x2+0.25x4+0.32x7+0.32x8 ≤7.5
14) S1
0.15x7+0.15x8 ≤1.8
15) SR
x5 ≤20
16) SR 4
0.2x5 ≤7.5
17) TW
0.25x3 ≤500
18) W1

34x1+34x2+7x3+32x4 ≤2000

19) W2
7x1+7x2+7x4 ≤500

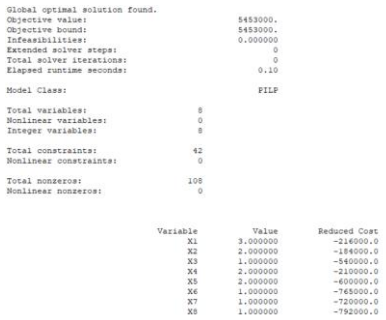
d. Highest Demand Constraints Son Polish
1) Son Pray
x1 ≥3
2) Son Jelly
x2 ≥2
3) Son Talas
x3 ≥1
4) Tire Polish
x4 ≥2
5) Son Black
x5 ≥2
6) Son R
x6 ≥1
7) Compound Kasar
x7 ≥1
8) Compound Halus
x8 ≥1

4. Integer Limits
Integer constraints in the integer model serve to state that decision variables are in integer form. Therefore, the integer constraint is formulated as:

$$x1, x2, x3, x4, x5, x6, x7, x8 \in \text{integer}$$

Integer Programming Optimization Results

From the formulation of the model that has been defined in the lingo framework, then click "Solve" to get the result of the decision variable. Based on the model above, the following decision variables are obtained:



```
Global optimal solution found.
Objective value:                              5453000.
Objective bound:                              5453000.
Infeasibilities:                              0.000000
Extended solver steps:                               0
Total solver iterations:                             0
Elapsed runtime seconds:                          0.10

Model Class:                                      PILP

Total variables:                     8
Nonlinear variables:                 0
Integer variables:                   8

Total constraints:                  42
Nonlinear constraints:               0

Total nonzeros:                    108
Nonlinear nonzeros:                  0


                     Variable           Value        Reduced Cost
                           X1        3.000000           -216000.0
                           X2        2.000000           -184000.0
                           X3        1.000000           -540000.0
                           X4        2.000000           -210000.0
                           X5        2.000000           -600000.0
                           X6        1.000000           -765000.0
                           X7        1.000000           -720000.0
                           X8        1.000000           -792000.0
```

Figure 1. Decision Variables of the Integer Programming Model in Lingo Software

Based on the results of the optimization of the integer programming model using lingo software, the value of the decision variables was obtained namely X1 = 3, X2 = 2, X3 = 1, X4 = 2, X5 = 2, X6 = 1, X7 = 1, and X8 = 1. The results of the optimization show the optimal production amount by considering the limited resources owned by Son Polish such as the capacity of workstation working hours for each product, shrink packing machine capacity and raw material capacity as well as the highest demand for each Son Polish product. So, the production combination that produces maximum profit is by producing 3 batches of Son Spray 3, 2 batches of Son Jelly, 1 batch of Son Talas, 2 batches

of Tire Polish, 2 batches of Son Black, 1 batch of Son R, 1 batch of Compound Kasar, and 1 batch of Compound Halus.



Figure 2. Solver Status of Integer Programming Model in Lingo Software

is a status solver from the result of completing integer programming, based on the solver status shows the maximum value of the destination function of Rp. 5,453,000. The optimization results also show that all constraints in this model have been perfectly met by indicating the value of infeasibility = 0. In the solution to this model, the Branch and Bound method (B – and – B) is used.

Discussions

The integer programming approach in this study was carried out with the aim of determining the optimal combination of production quantities in each Son Polish product. The integer programming model is prepared by considering the company's resources which include, the capacity of working hours of each workstation, the capacity of raw materials and the capacity of the machine. In addition, the model also uses the highest demand on each Son Polish product based on the demand history for the period July 2025 – December 2025. Based on the results of the analysis that has been carried out, the results of the combination decision variable of the optimal number of Son Polish products are obtained as follows:

Table 8. Integer Programming Decision Variables for Optimal Combination of Son Polis Products

Product	Variables	Batch Amount
Son Spray	x1	3
Son Jelly	x2	2
Son Talas	x3	1
Tire Polish	x4	2
Son Black	x5	2
Son R	x6	1
Coarse Compound	x7	1
Fine Compound	x8	1

Based on the results of the decision variables obtained in the table, the following are the results of a comparison of the profits obtained by Son Polish:

Table 9. Son Polish Profits for the Period of December 2025

PROFIT PERIOD DECEMBER 2025			
Product	Profit (Batch)	Production Amount/Month (Batch)	Profit
Son Spray	Rp. 216,000	45	Rp. 9,720,000
Son Jelly	Rp. 184,800	30	Rp. 5,544,000
Son Talas	Rp. 540,000	10	Rp. 5,400,000
Tire Polish	Rp. 210,000	35	Rp. 7,350,000
Son Black	Rp. 600,000	30	Rp. 18,000,000
Son R	Rp. 765,000	9	Rp. 6,885,000
Compound Kasar	Rp. 720,000	13	Rp. 9,360,000
Compound Halus	Rp. 792,000	17	Rp. 13,662,000
Profit/Month			Rp. 75,921,000
Profit/Day			Rp. 3,036,840

Table 10. Results of Integer Programming Decision Variables for Optimal Combination of Son Polis Products

BENEFITS OF INTEGER PROGRAMMING OPTIMIZATION RESULTS			
Product	Profit (Batch)	Production Amount/Day (Batch)	Profit
Son Spray	Rp. 216,000	3	Rp. 648,000
Son Jelly	Rp. 184,800	2	Rp. 369,600
Son Talas	Rp. 540,000	1	Rp. 540,000
Tire Polish	Rp. 210,000	2	Rp. 420,000
Son Black	Rp. 600,000	2	Rp. 1,200,000
Son R	Rp. 765,000	1	Rp. 765,000
Compound Kasar	Rp. 720,000	1	Rp. 720,000
Compound Halus	Rp. 792,000	1	Rp. 792,000
Profit/Month			Rp136,365,000
Profit/Day			Rp5,454,600

From the results of this optimization, Son Polish can earn a profit of Rp. 136,365,000.00/month or Rp. 5,454,600.00/day. Thus, it can be concluded that the implementation of optimization of the production volume of Son Polish is able to increase profits by Rp. 60,444,000.00/month or Rp. 2,417,760.00/day. These results show that an optimal production combination through the Integer Programming model can make a significant contribution to Son Polish's profitability by considering the resources the company has.

The results of this study show that the integer programming model can be used to determine the optimal combination of production amounts in Son Polish by considering the limited resources available. These findings are in line with research [4], that applied Integer Linear Programming with the Branch and Bound method in production optimization at the bakery, as well as the research [14] that used Mixed Integer Programming to optimize profits at D'Laundry Factory Pekanbaru. The similarities between this study and previous research lie in the use of integer programming approaches to obtain optimal solutions. However, the difference lies in the characteristics of the constraints used. This study not only considers aspects of profit and production capacity,

but also includes the raw time of each workstation, raw material capacity, machine raw time, and the highest demand based on historical data from July 2025 to December 2025. Thus, the model built can provide optimization results that are more in line with the actual production conditions of Son Polish.

CONCLUSION

Based on the results of the integer programming model obtained, the combination of the optimal production amount and being able to provide maximum profits by considering Son Polish resources is by producing 3 batches of Son Spray, 2 batches of Son Jelly, 1 batch of Son Talas, 2 batches of Tire Polish, 2 batches of Son Black, 1 batch of Son R, Fine Compound as much as 1 batch and Crude Compound as much as 1 batch. With a profit obtained of Rp. 136,365,000.00/month or equivalent to Rp. 5,454,600.00/day.

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