Linear Programming for Palm Oil Industry

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Abstract— This study is to design a linear programming model for palm oil mill processing in order to optimize the production planning related to the supply-demand patterns and minimize the cost of production. To ensure the developed model based on a real life industry as a case is performing well, the verification and validation test should be carried out. This is proven by executing the Lingo codes in Lingo command window.

Keywords—linear programming, simplex method, optimize production, palm oil mill, Lingo

I. Introduction

ONE of the most ultimate factor affected to the production process is planning and scheduling of the goods in production and transportation system from one facilities to others. The problem encountered in this operation process is on how company to strive for maximizing the profit, while at the same time minimizing the production cost. Briefly, this is a fundamental process of a company to optimize their production planning which require an accurate forecasting demand method. To make accurate forecasting demand, it therefore requires the appropriate tool to do better planning of resources.

In this study, how to optimize production planning of a palm oil mill to be more accurately than relying on the traditional system (since this system as much determined by judgment method which is solely based on manager's decision; seasoned employees for an estimation made) is, therefore, required. Based on this reason, this study discusses Linear programming as an essential tool which is extensively used for analysis and solving resources allocation. Linear programming is as a mathematical model associated to the optimization problem of a standard form, either to maximize or minimize the objective function related to specific constraints.

Here, the development on the modeling of optimization has encouraged a number of new methods for solving Linear Programming problem. First, the Dantig's Simplex Method [1,2] that is widely used to solve Linear Programming problems due to its efficiency and practical in application. Second, the Khachiyan's ellipsoid method [3] that is to improve the polynomiality of linear programming. Third, Karmarkar's interior-point method [4] that is not only demonstrate better complexity than the simplex method but also reported is to be more superior then simplex method, especially when it comes into some large-scale problem in practical applications.

Hence, this study takes a special interest on developing the mathematical model in linear programming using simplex method.

II. Research Environment

In this study, we use the simplex method to solve the problem in the palm oil industry. The simplex method employed is with the basic steps called "phases". After a feasible solution to the problem is found; the simplex method works by initial allocate a basic feasible solution to the problem is followed by subsequently selecting the solution from vertex to vertex along the edge of feasible solution. This way will cause the objective function increase for maximization problem and decrease for minimization problem in order to improve the value of the objective function. Thus, through a few iterations of this simplex method will converge to the optimum.

The operation process of palm oil mill comprised of the following: FFB reception and Handling Station, Sterilization Station, Tipper and Thresher Station, Press Station, Kernel Plant, Clarification Station, Storage, Boiler Station, Power Station. Starting from incoming inspection upon receiving FFB, delivered into the process line and finally to the final products which are;

A. Crude Palm Oil (CPO)

Crude palm oil is the crude oil derived from mesocarp using mechanical extraction which will later be refined, bleached and deodorized in refinery and carefully developed into variety of edible oil for use as margarine, cooking oil, shortening or powdered imitation milk creamers. In addition, the high melting point and long lasting scents have also made crude palm oil a good choice to serve as a preferable ingredient in cosmetic, soap, candles and detergents.

B. Palm Kernel (PK)

The composition of palm kernel together with its natural resembling makes it an ideal ingredient in the development and production of soaps, washing powders and personal care products. The speciality of palm kernel oil when it is eaten, it produces a softer texture and sweeter taste which lingers in the mouth. Thus, it is often used in the pharmaceutical, confectionery industry; enhancing these products soft

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sensation and making them last longer. Besides, palm kernel oil is used in non-food applications such as perfume industry, fuel and biodiesel or industrial materials.

In addition, the author thinks that in a highly competitive environment of upstream oil palm industry. When an oil mill intend to maintain market share position as a upstream player and further increase competitiveness, a better planning of their production optimization are crucial in provide cost effective and quality product to all the customer.

To accomplish this research, all the process in the mill was made available and all the data needed are accessible through their documentation, records and reports.

III. Model Development

To formulate palm oil mill problem as a linear programming, it will begin by defining the relevant decision variables. The decision variables are completely describing the decision to be made. Clearly, oil mill must decide the total amount of FFB should be purchased, the total amount of CPO and PK should be produced, total overtime required for each month to achieve optimal production during the planning period.

A. Decision Variables

FFB = Monthly fresh fruit bunch in metric ton which being purchased

a_1= Monthly fresh fruit bunch in metric ton which actually entered process line

w_1= Monthly overtime hours

Products which dispatch to each refinery, we define (for *i*= 1,2 and *j* = 1,2,3,4)

Let x_{ij} be the number of product produced *i* and dispatch to refineries *j*

x_{11} = Monthly CPO produced in metric ton and dispatch to refinery A

x_{12} = Monthly CPO produced in metric ton and dispatch to refinery B

x_{13} = Monthly CPO produced in metric ton dispatch to refinery C

x_{14} = Monthly CPO produced in metric ton dispatch to refinery D

x_{21} = Monthly PK produced in metric ton dispatch to refinery A

x_{22} = Monthly PK produced in metric ton dispatch to refinery B

x_{23} = Monthly PK produced in metric ton dispatch to refinery C

x_{24} = Monthly PK produced in metric ton dispatch to refinery D

B. Linear Programming Formulation

Setting the objective function and all the constraints involved to ensure that the linear programming model can replicate the real processing system of the oil mill. The linear programming model developed is presented as follows.

$$Max\ Z = 3175(x_{11} + x_{12} + x_{13} + x_{14}) + 1521\ (x_{21} + x_{22} + x_{23} + x_{24}) - 614FFB - (600)(8) - (3.75)(8)(w_1) - (2.87)(39.41)\left(720 - \frac{a_1}{45}\right) - 0.24a_1 - 0.28\ a_1 - 8.35\ a_1 - 36.1x_{11} - 40.95x_{12} - 40.95x_{13} - 36.1x_{14} - 39x_{21} - 43.96x_{22} - 43.96x_{23} - 39x_{24} \quad (1)$$

Subject to

$$x_{11} + x_{12} + x_{13} + x_{14} \leq 0.24\ a_1 \quad (2)$$

$$x_{21} + x_{22} + x_{23} + x_{24} \leq 0.04a_1 \quad (3)$$

$$(x_{11} + x_{12} + x_{13} + x_{14}) \geq MD_{cpo} \quad (4)$$

$$(x_{21} + x_{22} + x_{23} + x_{24}) \geq MD_{pk} \quad (5)$$

$$a_1 = 0.9957\ (FFB) \quad (6)$$

$$\frac{a_1}{45} - D_{ot} = 8\ (26) \quad (7)$$

$$D_{ot} - w_1 \leq 0 \quad (8)$$

$$w_1 \leq 5(26) \quad (9)$$

$$\frac{(x_{11}+x_{12}+x_{13}+x_{14})}{26} \leq 5000 \quad (10)$$

$$\frac{(x_{21}+x_{22}+x_{23}+x_{24})}{26} \leq 360 \quad (11)$$

$$w_1, a_1, x_{11}, x_{12}, x_{13}, x_{14}, x_{21}, x_{22}, x_{23}, x_{24}, MD_{cpo}, MD_{pk}, FFB \geq 0 \quad (12)$$

The objective function developed in (1) is designed to achieve the optimal solution to the company problem which are maximize profit For the palm oil mill problem, some of cost variables identified are such as fuel and power, water supply, upkeep machinery and processing chemical that is increasing linearly associated to fixed cost with respect to fresh fruit bunch which actually enter process line,a_1. The objective function can be stated as (monthly revenues) - (raw material purchased) - (other variables cost). The supply of FFB is modeled by constraints (2)-(3). Since the supply of FFB is fluctuating, thus it is necessary to forecast the FFB received to obtain the amount of product where the mill is able to supply. The demand of CPO is modeled by constraints (4) and (5). The demand constraints are much depending on monthly demand of CPO by refineries. In this study, the demand has been forecasted using trend projection with regression. Actual FFB processed is modeled by constraint (6). Upon receiving the raw materials from suppliers, the raw materials will undergo an incoming inspection. During the incoming inspection, the raw material which found off spec will be removed and the remaining of the raw material will then enter the processing line. The overtime planning is modeled by the constraints (7)-(9). Usually, during high crop season, extra processing hours is needed in order to clear off all the raw material received within 48 hours to avoid the rise in Free Fatty Acid and deteriorate the quality of the output product. For this very reason, the overtime payment must be made to the workers or operators for extra working hours. The storage capacity of the oil mill is modeled by the constraints (10)-(11). The product outcome will temporary stored at oil storage tank for CPO and dispatch to buyers daily. Finally, constraint (12) forces non-negativity in the model.

IV. The Problem and Solution Methodology

The mill is processing at throughput 45 metric ton per hour. The mill process line consists of 9 stations. Oil mill processes every metric ton of Fresh Fruit Bunch (FFB) to extract two types of final product; 24% of CPO and 4% of PK. Each metric ton of FFB is purchased at RM 614. While the selling price for each metric ton of CPO is RM 3175 and PK is RM1521. Every station consists of 8 operators to handle the station in mill. The minimum salary paid for each operator is RM2.50 per hour for normal working hours, while RM 3.75 per hour for overtime. The processing of each metric ton of FFB will cost RM 0.24 for water supply, RM 0.28 for processing chemical and RM 8.35 for upkeep machinery.

There are several assumptions we made when developing and executing the model. The assumption as follows;

(1) The mill is achieving its designed throughput

(2) There is no delay during start up

(3) Process are assumed to be in control

(4) The upkeep machinery and the processing chemical cost are fixed.

By using the mathematical model proposed from (1) to (12), the model need to be verified and validated to ensure that the developed model is performing well based on the replicating of the real processing system using Lingo codes and executed by running Lingo.

V. Results and Discussions

A. Verification of the model

Once the linear programming model has been developed, it is important to verify that the Lingo codes which converted from the linear programming model are functioning well. This was proven by executing the Lingo codes in Lingo command window. Once the Lingo codes are cleared from any mathematical or logical errors, it results a feasible, bounded form with optimum solution it is verified as functioning well. An optimum solution will be obtained based on the linear programming converted Lingo codes. Table I presenting the comparison of optimum result obtained from production optimization by using Excel with the optimum result obtained from the Lingo simulation.

Table I shows the result obtained from running the linear programming model in excel and Lingo. They are almost the same with a different of RM 3 (RM2448733- RM2448730). Therefore, it can be concluded that the linear programming model have been verified. After the development and verification of the proposed linear programming model, the next step validation of model is important to confirm that the proposed model is able to replicate the real palm oil mill processing system in order to obtain a reliable result. The approach on the model validation of the proposed model will be discussed in the next section.

TABLE I
RESULTS OBTAINED FROM EXCEL AND LINGO

Variables	Solution by using Excel	Solution by using Lingo
x_{14}	3193.276	3193.278
x_{24}	532.2128	532.2129
w_1	87.6737	87.6738
a_1	13305.32	13305.32
Profit	2448730	2448733

B. Validation of the model

Since the validation carried out is to identify how close and accurate the established linear programming model with the real life system, there are found no significant differences between the proposed models with the available real system. For that reason, we use the result generated from the linear programming model and compared with real life industry result obtained from respective oil mill. The result obtained from Lingo shows that the optimal solution representing the profit of the oil mill is RM2, 448,730 (Fig. 1), whereas the actual profit from the palm oil mill is RM2, 232, 600. By using the developed linear programming model, it shows that an average of 9.68% of the profit has been optimized.

VI. Conclusion

This study has successfully develops a linear programming model which can accurately replicate the real palm oil mill processing system. The test result of the proposed model is close enough to real industry application (generated by Lingo). The result obtained seems to be promising. Future study are required by extending the model subjected with more detail processing system which include more factors affected to the process such as the delay in the processing line of each station which will cause lesser throughput and the influences of the oil and kernel extraction rate. This is due the rate of oil and kernel extraction are, in facts, will never be constant to quality of process control. In addition, since in this study that the process is in control, we see that the condition of the machinery or mill with the break down condition can be considered as a scenario in future work. This will give more realistic and accurate result for optimize production planning.

References

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Global optimal solution found.
Objective value:                              2448733.
Infeasibilities:                              0.000000
Total solver iterations:                             0

Model Class:                                        LP

Total variables:                      9
Nonlinear variables:                  0
Integer variables:                    0

Total constraints:                   19
Nonlinear constraints:                0

Total nonzeros:                      43
Nonlinear nonzeros:                   0

                              Variable           Value        Reduced Cost
                                   X11        0.000000            0.000000
                                   X12        0.000000            4.850000
                                   X13        0.000000            4.850000
                                   X14        3193.278            0.000000
                                   X21        0.000000            0.000000
                                   X22        0.000000            4.960000
                                   X23        0.000000            4.960000
                                   X24        532.2129            0.000000
                                    W1        87.67385            0.000000
                                    A1        13305.32            0.000000
                                    YJ        87.67385            0.000000
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Fig. 1 Result generated from Lingo