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Mixed Integer Linear Programming model for Crude Palm Oil Supply Chain Planning

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Abstract. The production process of crude palm oil (CPO) can be defined as the milling process of raw materials, called fresh fruit bunch (FFB) into end products palm oil. The process usually through a series of steps producing and consuming intermediate products. The CPO milling industry considered in this paper does not have oil palm plantation, therefore the FFB are supplied by several public oil palm plantations. Due to the limited availability of FFB, then it is necessary to choose from which plantations would be appropriate. This paper proposes a mixed integer linear programming model the supply chain integrated problem, which include waste processing. The mathematical programming model is solved using neighborhood search approach.

1.   Introduction

Jha Crude palm Oil (CPO) industry could belong to a business which needs a network system, as this product is not an end-product. The network system which performs the functions of procurement of materials, processing these materials into intermediate and finished products, and the distribution of these intermediate/ finished products to customers, is called supply chain system. All these facilities are used for fulfilling a customer request. The challenges of supply chain are to produce the right products, in the right quantities, at the right place, at the right time and at appropriate cost.

Due to the complexity of decision making process in supply chains, it is necessary to use modeling techniques that can help identify and implement strategies for designing high performance supply chain networks [10, 13, 14]. The main reasons to use model for the decision making process are large scale nature of the supply chain networks, hierarchical structure of decisions, randomness of various inputs and operations, and dynamic nature of interactions among supply chain elements [10]. Optimization model has become a high technology in supply chain planning and management [4, 5, 7].

Nasiri [6] presented the modelling of an integrated the supply chain system which involve raw material suppliers, several plants, distribution centres, warehouses and customers. Piewthongngam [11] analysed more complicated case for the integrated supply chain. They considered the supply chain case which involved multiple feed mills, multiple plantation, and multiple products. Timpe and Kallrath [2] addressed a mixed integer linear programming model, which integrate production, distribution and

marketing and involved plants and sales points. Their paper describes how to cover the relevant features required for the supply chain management along with a multi-site production network.

Dumrongsiri [1] proposes the production planning of palm oil and the capacity planning of palm oil processing plants in Thailand. He creates a mixed integer linear programming model for the integrated production planning. Chungsiriporn [9] use a nonlinear programming model for CPO production planning with minimization of water consumption at the milling process. However they only consider the optimization process to get the CPO. Another CPO production planning which consider only at the milling process is discussed in Amelia [12]. They consider fuzzy logic approach to provide a simpler mechanism in order it would be possible to find the relationship between the processing variables and the amount of CPO and palm kernel losses. Suksa-ard and Reaweewan [3] develop an optimization model in s supply and demand system for a CPO production planning. Their model is to decide which market of CPO should be selected, and also to find out how much demand should be served in the selected market. Sadyadharma [8] present a multi-objective optimization model for a sustainable production planning of CPO considering uncertainty in the reliability of financial risk.

2.   Problem Description

The production process of crude palm oil (CPO) can be traced as the milling process of fresh fruit bunch (FFB) into end products palm oil. The process usually through a series of steps producing and consuming intermediate products. These FFB, intermediate and end products (CPO) are necessarily to be inventoried, allowing one to produce and consume them at different moments and rates in time. It should be noted for palm oil the time to keep FFB in inventory is very short.

We consider a CPO milling company who own *j* milling factories, however the company does not have its own palm plantation. In order the company would be able to produce CPO from its millings, it needs to buy FFB from *I* public palm plantations. The situation is thus the same as in the two-echelon supply chain system. The management needs to decide from which palm plantation to serve the milling factory and then to put the CPO into inventory (warehouse) afterward to deliver the CPO to the *k* customers.

3.   Mathematical Model

According In this case, the CPO companies is to decide optimally
1. From which palm plantation the FFB should be bought
2. Quantity of FFB to be bought from the chosen palm oil plantation
3. Quantity of CPO to be produced
4. Quantity of CPO to be delivered to each customer
5. Quantity of Waste produced in the milling process such that to minimize the overall operational costs.

There are several assumptions are necessary to be considered..
1. FFB are always available from palm oil plantations,
2. The demands of CPO from customers are deterministic,
3. Out of stock never occur.

Notations to be used.
Decision variables

x_{ij}^t Quantity of FFB (ton) to be bought from plantation I for milling j in time period t

y_j^t Quantity of CPO (ton) to be produced at milling j in time period t

z_{jk}^t Quantity of CPO (ton) to be delivered from milling j to customer k in time period t

v_j^t Quantity of liquid waste (ton) produced after the milling process in milling j in time period t

w_j^t Quantity of solid waste (ton) produced after the milling process in milling j in time period t

δ_{ij} A binary variable which is 1 if FFB for milling j is bought from plantation I and zero otherwise

Parameters

α_{ij} Transportation cost (Rp.) from plantation I to milling j per kilometer

d_{ij} Distance (km) from plantation I to milling j

β_j Production cost (Rp.) at milling j

γ_{jk} Transportation cost (Rp.) to deliver CPO from milling j to customer k

λ_j Cost (Rp.) for processing liquid waste at milling j

ρ_j Transportation cost (Rp.) for solid waste at milling j

τ_{ij}^t Overall price (Rp.) to buy FFB from plantation i for milling j in time period t

Cm_j^t Milling capacity (ton) at milling $j \in J$ in time period $t \in T$

CP_j^t Production capacity (ton) at milling $j \in J$ in time period $t \in T$

CA_i^t Quantity of FFB (ton) available at plantation $i \in I$ in time period $t \in T$

Sets are defined as follows.

I denotes the set of oil palm plantations

J denotes the set of CPO milling

K denotes the set of customers

T denotes the set of time period

The objective of the decision to be made is to minimize the overall operational costs. Mathematically the objective function can be expressed as follows:

$$Minimize \quad \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} (\tau_{ij})(d_{ij}) x_{ij}^t + \sum_{j \in J} \sum_{t \in T} \beta_j y_j^t + \sum_{j \in J} \sum_{k \in K} \sum_{t \in T} \gamma_{jk} z_{jk}^t +$$
$$\sum_{j \in J} \sum_{t \in T} \lambda_j v_j^t + \sum_{j \in J} \sum_{t \in T} \rho_j w_j^t + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \alpha_{ij} \delta_{ij}^t \tag{1}$$

There are several requirements must be met regarding to limit the decision variables.

$$\sum_{i \in I} x_{ij}^t \le Cm_j^t \qquad \forall j \in J, t \in T \tag{2}$$

$$\sum_{j \in J} \sum_{t \in T} y_j^t \le \sum_{j \in J} \sum_{t \in T} Cp_j^t \tag{3}$$

$$\sum_{i \in I} x_{ij}^t \le \sum_{i \in I} CA_i \delta_{ij}^t \qquad \forall j \in J, t \in T \tag{4}$$

$$\sum_{j \in J} z_{jk}^t \le \sum_{j \in J} y_j^t \qquad \forall k \in K, t \in T \tag{5}$$

$$v_j^t + w_j^t \le \sum_{i \in I} x_{ij}^t \qquad \forall j \in J, t \in T \tag{6}$$

$$\sum_{i \in I} \sum_{j \in J} \delta_{ij} = n \tag{7}$$

$$x_{ij}^t, y_j^t, z_{jk}^t, v_j^t, w_j^t \geq 0, \quad \delta_{ij} \in \{0,1\}, \quad \forall i \in I, j \in J, k \in K, t \in T \tag{8}$$

Expression (2) states that the quantity of FFB to be bought from oil palm plantation $i \in I$ for milling $j \in J$ should be $\leq$ to the capacity of milling $j \in J$ in time period $t \in T$ Constraint (3) describes that the quantity of FFB to be processed in milling $j \in J$ should be $\leq$ to the production capacity of milling $j \in J$ in time period $t \in T$ .Constraint (4) presents that the quantity of FFB to be bought from oil palm plantation $i \in I$ for milling $j \in J$ should be $\leq$ to the availability of FFB in the plantation $i \in I$, if the plantation is chosen, in time period $t \in T$ Equation (5) to state that the quantity of CPO to be delivered to customer $k \in K$ from milling $j \in J$ should be $\leq$ to the quantity produced in milling $j \in J$ in time period $t \in T$ Constraint (6) represents the quantity of solid and liquid waste from milling $j \in J$ should be $\leq$ the quantity of FFB have been processed in time period $t \in T$ .Expression (7) is to ensure that there would be only n plantation available to supply FFB for each milling $j \in J$. Constraints (8) state the type of decision variables.

4.   Algorithm
Let
$$x = [x] + f, 0 \leq f \leq 1$$
be the (continuous) solution of the relaxed problem, [x] is the integer component of non-integer variable *x* and *f* is the fractional component.
Stage 1.

Step 1.   Get row i* the smallest integer infeasibility, such that $\delta_{i*} = \min\{f_i, 1 - f_i\}$
(This choice is motivated by the desire for minimal deterioration in the objective function, and clearly corresponds to the integer basic with smallest integer infeasibility).

Step 2.   Do a pricing operation
$$v_{i*}^T = e_{i*}^T B^{-1}$$

Step 3.   Calculate $\sigma_{ij} = v_{i*}^T \alpha_j$
With *j* corresponds to
$$\min_j \left\{ \left\| \frac{d_j}{\alpha_{ij}} \right\| \right\}$$
Calculate the maximum movement of nonbasic *j* at lower bound and upper bound.
Otherwise go to next non-integer nonbasic or superbasic *j* (if available). Eventually the column j* is to be increased form LB or decreased from UB. If none go to next i*.

Step 4.   Solve $B\alpha_{j*} = \alpha_{j*}$ for α_{j*}

Step 5.   Do ratio test for the basic variables in order to stay feasible due to the releasing of nonbasic j* from its bounds.

Step 6.   Exchange basis

Step 7.   If row i* = {∅} go to Stage 2, otherwise
Repeat from step 1.

Stage 2.

Pass 1:   adjust integer infeasible superbasics by fractional steps to reach complete integer feasibility.

Pass 2:   adjust integer feasible superbasics. The objective of this phase is to conduct a highly localized neighborhood search to verify local optimality.

5.   Conclusion

In this paper, we consider an integrated supply chain production – distribution planning faced by decision maker (DM) of a CPO milling industry. This industry needs to buy FFB from several oil palm plantation. Due to the limited availability of FFB then the DM has to decide from which plantations would be appropriate to meet the production capacity of the milling industry. We develop a mixed integer linear programming model for the integrated of production and distribution planning problem of the crude palm oil industry. We solve the model using a direct search approach.

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