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Production Optimization Design in Supply Chain Crude Palm Oil with Genetic Algorithm Method

Meilita Tryana Sembiring, Prayogo Suryawan, M. Haikal Karana Sitepu, and Sawaluddin

Department of Industrial Engineering, Faculty of Engineering, University Sumatera Utara

Abstract. Indonesia is the world's largest producer of *crude palm oil* (CPO). At peak harvest conditions, frequent accumulation of fresh fruit bunches (FFB) due to abundant raw materials. Based on data from one palm oil mill in the province of North Sumatra, the percentage of FFB stays in the field overnight, which is 41% of the total FFB though, on the one hand FFB that has been harvested must be processed immediately because it can affect the quality of oil to be produced. Besides that, the factors of production and storage processes are also very influential on the quality of CPO. The imbalance in production planning shows that production planning is not yet optimal in the CPO supply chain so that a production optimization design is needed in the CPO supply chain. The genetic algorithm was chosen in the completion of the optimization model because of the complex characteristics of the CPO supply chain. The purpose of this research is to optimize the palm oil supply chain system to minimize production costs. This method shows that the optimum production yield for the third quarter of 2017 is 12,202,285 kg. With the proposed system an increase in the percentage of CPO production was obtained by 8.34% compared to the actual system.

Keyword: Genetic Algorithms, *Crude Palm Oil*, Optimization, Supply Chain

Abstrak. *Indonesia adalah produsen crude palm oil (CPO) terbesar di dunia. Pada kondisi puncak panen, sering terjadi penumpukan Tandan buah segar (TBS) karena bahan baku yang melimpah. Berdasarkan data pada salah satu pabrik kelapa sawit di provinsi Sumatera Utara, persentase TBS menginap dilapangan selama satu malam yaitu sebesar 41% dari keselurahan TBS olah, di satu pihak TBS yang telah dipanen harus segera diproses karena dapat mempengaruhi kualitas minyak yang akan dihasilkan. Selain itu faktor proses produksi dan penyimpanan juga sangat berpengaruh terhadap kualitas CPO. Ketidak-seimbangan perencanaan produksi menunjukkan belum optimalnya perencanaan produksi pada rantai pasok CPO sehingga diperlukan suatu rancangan optimasi produksi pada rantai pasok CPO. Algoritma genetika dipilih dalam penyelesaian model optimasi karena karakteristik rantai pasok CPO yang kompleks. Tujuan dari penelitian ini yaitu mengoptimasi sistem rantai pasok minyak sawit untuk meminimumkan biaya produksi. Metode ini menunjukkan hasil produksi optimum untuk Triwulan III 2017 adalah sebesar 12.202.285 kg. Dengan sistem usulan diperoleh peningkatan persentase produksi CPO sebesar 8,34% dibandingkan sistem aktual.*

Kata Kunci: *Algoritma Genetika, Crude Palm Oil, Optimasi, Rantai Pasok*

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*Corresponding author at: Department of Industrial Engineering, Faculty of Engineering, University Sumatera Utara, Medan, Indonesia

E-mail address: meilita_tryana@yahoo.co.id

1 Introduction

Since 2006 Indonesia has become the world's largest producer of *crude palm oil* (CPO) with production reaching 34 million tons in 2016. In order to accelerate the downstreaming of palm oil in the country, the government has changed the export tax policy to a policy CPO Export Duty and its derivative products. The downstream progress that occurred in the 2011-2016 period was reflected in domestic CPO consumption from 7.8 million tons to 13.5 million tons. With the further development of the national downstream palm oil industry, the need for raw materials in the form of *crude palm oil* (CPO) will increase.

The CPO production process has a value chain from post harvest to oil palm plantations, transportation of raw materials, processing of palm oil to CPO and storage. At peak harvest conditions, there is often a buildup of FFB due to abundant raw materials. Based on data for July 2017 in one of the PKS in North Sumatra, the percentage of FFB staying in the field for one night is 41% of the total FFB. The source of raw materials (FFB) used comes from company-owned plantations, with a total of eight supplier gardens. on the one hand FFB that has been harvested must be processed immediately because it can affect the quality of the oil quality to be produced. The cost of transporting FFB from each farm also varies due to the distance between the different plantations and factories. Besides that, the factors of production and storage processes are also very influential on the quality of CPO.

Based on the background that has been described, the formulation of the problem in this study is that the production planning in the CPO supply chain is not yet optimal which is characterized by an imbalance in production planning. This imbalance causes losses both directly and indirectly to the company.

In connection with the above problems, it is necessary to design an optimization of the supply chain crude palm oil that can be implemented so that the number of products that must be produced for cost minimization is known without ignoring the limitations of the company using the genetic algorithm method.

2 Research Methods

The study began with a review and data collection at PKS XYZ. The research object observed was the CPO supply chain which included the availability of FFB, the transportation of raw materials, the CPO production process and the CPO stockpiling. Data collected from company documents, interviews and direct observations. The steps taken in data processing are as follows:

2.1 Targeting Constraint Modeling

Constraint function is needed so that the *output* to be obtained can be applied. This constraint function is obtained from the limitations that exist in the company. Following are the function constraints that exist in the CPO PKS XYZ production process:

1. Availability of FFB

   The first obstacle is the availability of FFB from each farm. The number of FFB processed must not exceed the availability of existing FFB. The mathematical formulation is as following:

$$X_{it*} \leq \check{A}_{it} \tag{1}$$

2. The production volume

   The second constraint is the production volume of CPO produced in accordance with TBS supply. The raw material in the form of FFB to be processed must meet company standards, therefore FFB will be inspected before processing. The yield factor will also affect the CPO produced.

$$X_{9t} = \sum_{i=1\, t=1} rs_{it} e_t \tag{2}$$

The amount of CPO produced cannot be less than the production target.

$$X_{9t} \leq M_t; \tag{3}$$

The number of FFB if it can not exceed the factory capacity.

$$X_{9t} \leq KP \tag{4}$$

3. Inventory

   The third obstacle is controlling CPO in the storage tank. The amount of CPO in the storage tank is influenced by several factors, namely the amount of CPO in the tank in the previous period, the amount of CPO currently produced and the current number of CPO requests.

$$X_{10t} = X_{10t-1} + X_{9t} - M_t \tag{5}$$

Safety stock policies that must be met must also be considered.

$$X_{10t} \geq SS_t \tag{6}$$

CPO supplies may not exceed the capacity of the storage tank.

$$X_{10t} \leq KT \tag{7}$$

4. Need for Trucks

The fourth obstacle is the need for FFB transport trucks not to exceed the available trucks.

$$X_{it} \leq KA_{it} \quad (8)$$

The number of trucks used must also not be less than the transport requirements of a certain period. The formulation can be seen as follows:

$$X_{it} \geq \frac{X_{it*}}{R_{it}.wd_t.G} \quad (9)$$

2.2 Function Modeling Purpose

The objective function of this mathematical model is the minimization of total costs consisting of the acquisition costs of FFB, CPO production costs, CPO hoarding costs and the cost of transporting FFB from the garden to the mill. Min Z =

$$\left(\sum_{t=1}^{i=1} p_{it}X_{it*}\right) + b_t X_{9t} + d_t X_{10t} + \left(\sum_{t=1}^{i=11} h_{it}X_{it}\right) \quad (10)$$

The parameter notations used in the constraint function can be seen in Table 1.

Table 1 CPO Constraint Function Parameters

Notation	Information
$\bar{A}_{it}$	Forecast availability of FFB from plantation i in the t-period (tons)
KP	Availability of factory capacity
M_t	T-period CPO production target
rs_{it}	The yield factor of FFB from plantation i in the t-period
e_t	Percentage of FFB that does not meet specifications in the t-period
KT	Storage tank capacity
SS_t	The level of safety stock in the t-period
KA_{it}	Trucks available from garden i in the t-period
b_t	CPO production costs in the t-period
d_t	Cost in the storage tank in the t-period
p_{it}	Cost of obtaining FFB from plantation i in the t-period
G	Truck Capacity
h_t	Truck transportation costs in the t-period

J_i	Distance between Afdeling i to PKS
P_i	Number of truck trips per day
wd_t	Number of workdays t-period

The variable notation of the objective function can be seen in Table 2.

Table 2 CPO Supply Chain Decision Variable

Notation	Information
X_{it*}	Amount of FFB that must be sent from plantation i to the mill in the t-period * (i = 1,2,3 ..., 8)
X_{9t}	Total CPO production in the t-period
X_{10t}	Amount of stockpile in stock in the t-period
X_{it}	Number of trucks needed in garden i in the t-period (i = 11,12,13 ..., 18)

2.3 Completion of Optimization Model Using

Genetic Algorithms. Completion of the model will produce outputs that are useful in production planning. Completion of this optimization model is assisted by using software Matlab.

3 Results and Discussion

3.1 CPO Supply Chain Analysis The CPO

Supply chain system can be seen in Figure 1. The CPO supply chain system can be assessed from three aspects namely material flow, information and data flow, and money flow.

Information and data flow starts from the information demand provided by the final consumer to the retailer, then continues to the distributor and finally reaches the upstream agro-industry. This information and data will be forwarded to PT. XYZ Marketing. Information will then be passed on to the management of PT. XYZ, then proceed to PKS XYZ through the administration section, the administration section will provide information to the inventory section and the production section. Information to the section inventory in the form of how much CPO will be submitted to the distributor. While the information to the production department is the CPO production target that must be achieved, the production department also provides feedback in the form of production realization that has been achieved and is supported by information about the ability of utilities in the production process from the Technical section as well as CPO quality information and Rendemen from the Laboratory section. Information from PKS XYZ received by PT. XYZ will be forwarded to tier suppliers 1in the form of information on the needs of FFB that must be supplied to PKS XYZ. Final information will be conveyed from tier 1to suppliers tier suppliers 2in the form of how much fertilizer and pesticide needs.

Material flow starts from tier 2 suppliers who supply material needs for the garden (supplier tier 1) then the material will be transported through third parties to PKS XYZ. Material in the form of FFB will be sorted, where FFB that does not pass the sorting will be returned again to tier suppliers 1. followed by a distributor who will distribute to retailers. Through retailers material, it will reach the end consumers.

The flow of money starts from tier suppliers 1who purchase material to tier suppliers 2. The money flow will be continued to the transport of FFB from tier suppliers. Tier 11 suppliers themselves will receive cash flows from the management of PT. XYZ The flow of money will be continued from PT. XYZ to PKS XYZ through the Administration section. The flow of money will also occur between PT. XYZ with PT. Marketing XYZ. Products in the form of CPO are received by the agro-industry so that there is a cash flow from the agro-industry to PT. XYZ. The flow of money also occurs in distributors and retailers. Last is the flow of money that occurs from the end consumer with the retailer.

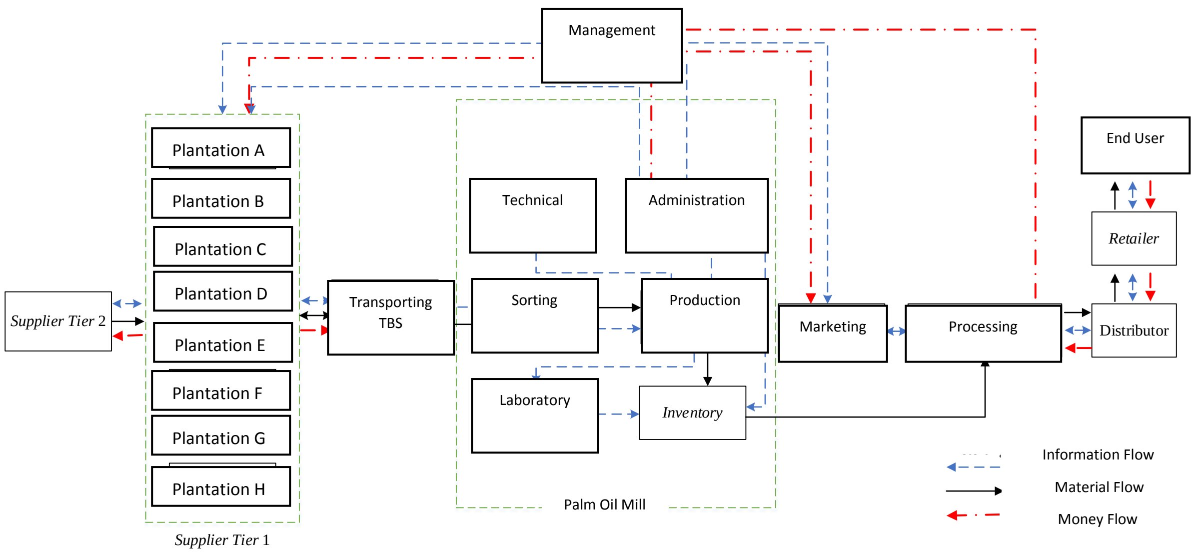

Figure 1 CPO Supply Chain System

3.2 Analysis of the Actual CPO Supply Chain System The Actual

Realization of the actual CPO production in June 2017 against the RKAP was 96.62%. Judging from the number of processed FFBs, the amount of FFB though on realization was greater to the RKAP, which was 667,340 kg. But this is inversely proportional to the value of the existing yield. Realization of the average yield only reached 22.19% while the RKAP yield value reached 24.04%. This is certainly very influential on the comparison of FFB though with the amount of CPO production.

Indication that causes the low value of yield is the inability of factories to process FFB. This condition can be seen from the data on fruit reception for the period of January to June 2017 in Figure 2.

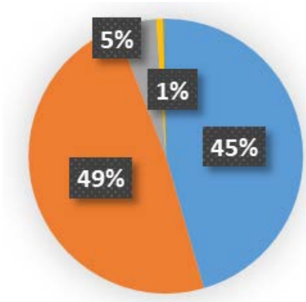

Figure 2 Average Percentage of FFB Stay Periods of January to June 2017

The high percentage of FFB stays does not only occur during peak harvest but also occurs during season with moderate production. Information supply chain system between PT. XYZ with the PKS XYZ and the Garden party that was not good caused the flow of material that had piled up on PKY XYZ. FFB that has been harvested must be processed immediately so there is no shrinkage in the value of the yield which will affect the cost of CPO production, besides the value of free fatty acids contained in FFB will also increase over time. The higher the ALB value contained in the CPO, the lower the selling price.

Realization yield value which only reached 22.19% was also caused by the supply chain information system between the estate and the transportation party which was not good. The contract system undertaken by the farmer and the FFB transporter is extended in each period with a certain transport value. If transportation has reached an agreement, the transportation party will stop to transport FFB even though it is still in the current period. To overcome this the farmer must enter into additional contracts but at a higher cost. Inadequate infrastructure in the farm also causes the FFB distribution process to be hampered. Poor access to plantations and factories will cause FFB to not be transported completely on the same day the fruit is harvested. But on the one hand, if the farm has good infrastructure, it is very vulnerable to theft of FFB on the farm.

3.3 Proposed Supply Chain Analysis

The results of genetic algorithm processing are assisted by using *software* Matlabto obtain the results shown in Table 3.

Table 3 Optimization Results Using Genetic Algorithm

Variable	Information	Value
X_1	FFB from graden A	11.422.249
X_2	FFB from graden B	672.662
X_3	FFB from graden C	7.906.636
X_4	FFB from graden D	2.622.435
X_5	FFB from graden E	9.775.531
X_6	FFB from graden F	14.704.867
X_7	FFB from graden G	666.953
X_8	FFB from graden H	7.493.574
X_9	The amount of CPO produced	12.202.285
X_{10}	The amount of CPO in the storage tank	389.117
X_{11}	The need for Gardens A trucks	14
X_{12}	The need for Gardens B trucks	1
X_{13}	The need for Gardens C trucks	6
X_{14}	The need for Gardens D trucks	5
X_{15}	The need for Gardens E trucks	7
X_{16}	The need for Gardens F trucks	16
X_{17}	The need for Gardens G trucks	3
X_{18}	The need for Gardens H trucks	11

In Figure 2, it can be seen that in the 312th generation only the highest fitness value is obtained which is also a minimum objective function of Rp.89,584,664,864.66. while for the Best Individual is in variable 6, followed by variable 9 and variable 1, while the weakest Individual is in variable 12.

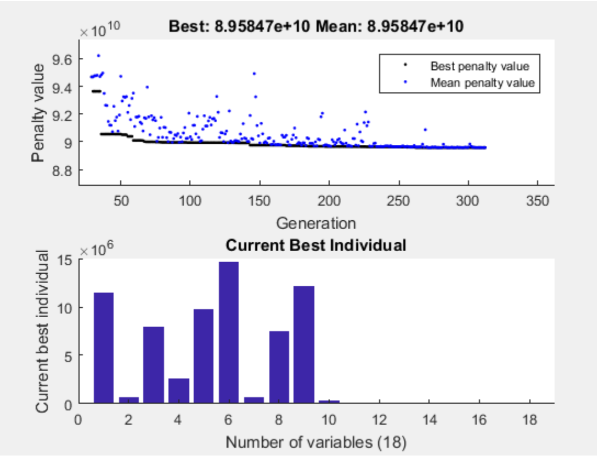

Figure 3 Fitness Value and Best Individual Production Optimization Design in the Crude Palm Oil Supply Chain

From the existing system, it is known that PKS XYZ is unable to process FFB directly because of limited production capacity. Therefore, with the integration of information and material system chains between tier suppliers, 1namely the plantation and PKS XYZ, as well as the integration of information systems internally in the engineering, production, laboratory, sorting, sections, inventory, and administration accurate information about if TBS needs are needed PKS XYZ. The information available can be used to manage good management of FFB distribution so there is no accumulation of FFB in PKS XYZ. This can also improve the quality of CPO and the yield produced. From the results of the processing that has been carried out, it is proposed that FFB amounting to 3,042,093 kg will be processed at the PT. The closest XYZ that still hasn't reached the maximum capacity which has a distance of 55 Km from the XYZ VFD. With the allocation of FFB processing, the yield value is expected to be in accordance with the RKAP value in the range of 24.04%. However, to implement this system companies must incur additional transportation costs.

Table 4 Comparison of The Number of Trucks Needed with The Availability of Trucks in Quarter III 2017

Unit Gardens	Truck Needed	Truck Availability
Garden A	14	17
Garden B	1	6
Garden C	6	16
Garden D	5	5
Garden E	7	16
Garden F	16	21
Garden G	3	3
Garden H	11	16

In Table 5, it can be seen that the needs of trucks for the third quarter of 2017 are met. This shows that the design of production optimization carried out is feasible to be applied. From this data it can also be seen that the transport capacity of each farm can still be improved except in D and Kebun G that have reached the transport capacity limit. Solution that can be given is by increasing the number of truck fleets. The integration of the information system supply chain between the transporter, the farmer, and the PKS XYZ will form a good system so that the shortage of FFB though the PKS XYZ due to the inability of the transport capacity can be avoided.

In Table 5. it can be seen that the needs of trucks for the third quarter of 2017 are met. This shows that the design of production optimization carried out is feasible to be applied. From this data it can also be seen that the transport capacity of each farm can still be improved except in D and Kebun G that have reached the transport capacity limit. Solution that can be given is by increasing the number of truck fleets. The integration of the information system supply chain between the transport party, the plantation, and the PKS XYZ will form a good system so that the shortage of FFB though on the PKY XYZ due to the inability of the can be avoided. This integration will also eliminate the number of FFB staying in temporary shelters in the garden so that there is no decrease in the yield and quality of CPO.

From the overall problem solving analysis that has been done, it can be concluded that there are several advantages of the proposed system compared to the actual system that can be seen from the comparison of the actual and proposed systems in Table 5.

Table 5. Comparison of Actual and Proposed Systems

No.	Actual System	Recommendation System
1.	The whole FFB recommendation system from eight supplier gardens is self-managed	Some of FFB is processed in other PKS
2.	TBS buildup occurs in PKS	There was no buildup of FFB on the PKS
3.	Have an average Yield of 22.19%	Have an average Yield of 24.04%
4.	CPO produced has a higher ALB value	CPO produced has a lower ALB value than the actual system
5.	CPO that can be produced is 12,938,323 kg	CPO that can be produced is 14,017,003 kg

The percentage increase in production ofof the proposed system against the actual system is:

$$= \frac{14.017.003 - 12.938.323}{12.938.323} \times 100\% \quad = 8{,}34\% \tag{11}$$

Implementation of the draft production optimization using genetic algorithms can increase the percentage of CPO production by 8.34% compared to the Actual system. This value shows a very good increase so it needs to be applied in the company's CPO production planning.

4 Conclusion and Discussion

Conclusions obtained from the results of data collection, processing and analysis that have been carried out, i.e. The number of FFB processed at PKS XYZ is 58,307,000 kg or 94.78% of the total availability of FFB and the rest is allocated to other PKS. Optimization results using a genetic algorithm were obtained after the 312th generation with the Fitness Value bestof Rp.89,584,664,864.66 and Best Individual, the 6th variable. The proposed supply chain system can increase the percentage of CPO production by 8.34% compared to the Actual system. The design of production optimization in the CPO supply chain using the genetic algorithm method shows the optimum production results for the third Quarter of 2017, amounting to 12,202,285 kg, with a total CPO stockpiling of 389,117 kg, and the need for trucks of 63 units.

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