A design of bi-objective optimization model palm refinery export supply chain network: a case study in Indonesia

Meilita Tryana Sembiring*, Saut Sejati Hutapea, M Zaky Hadi and Dini Wahyuni

Department of Industrial Engineering, Universitas Sumatera Utara, Medan, Indonesia, 20155

Abstract. One of the important elements influencing the export development of these products is the export distribution network produced by refining palm oil. The challenge of export distribution of palm oil refining products to generate maximum profit with minimum distribution costs, among others, is high transportation costs, distant transportation / logistics destinations, variations in product types and allocation of the number of products that must be distributed to consumers (foreign markets). The purpose of this study is to maximize profits and minimize distribution costs from the export distribution network of Indonesian palm oil refining products. Multiple goal optimization model (multi objective optimization) with the completion of soft-computing techniques is needed to solve this problem in order to get optimum results with a short solution search time. The NSGA-II algorithm (non dominated sorting algorithm II) was chosen in the completion of the existing optimization model because of the characteristics of the distribution network of export products resulting from complex refining of palm oil. The scenario used for testing the optimization model is by using a system entity consisting of three types of Indonesian palm oil refining products (Stearin RBD, Olein and PFAD RBD).

1. Introduction
Palm oil refining products are one of Indonesia’s leading products that have an important role in the country’s foreign and domestic (foreign exchange) foreign exchange producers. The Plantation Fund Management Agency (BPDP) stated that refined palm oil export products increased by 22% from 2016. One of the important elements influencing the export development of these products is the export distribution network produced by refining palm oil. The constituent elements of the export distribution network of refinery products are being developed. Efforts in developing the export distribution of palm oil refining products (refineries) aim to maximize profit and distribution costs can be minimized so that the number of products distributed can be increased. The challenge of export distribution of palm oil refining products (refineries) includes high transportation costs, distant transportation / logistics destinations, variations in product types and allocation of the number of products that must be distributed to consumers. This problem belongs to an integer programming problem that falls into the NP-Hard problem category (a non-deterministic polynomial problem), which means that the computational effort used will be increasingly difficult and more in line with the increasing scope of the problem with multiple (multi-objective) objectives in the export distribution activities of the results of refining palm oil into the hands of consumers. The integration of the management of export distribution of refined oil products is very important to create an optimal and sustainable distribution network[1][2][3][4].

Based on the background that has been described, the formulation of the problem in this study is that the export distribution network of palm oil refined products is not optimal yet to obtain a
minimum distribution cost and maximum total profit. In connection with the above problems, it is necessary to design an optimization model on the export distribution network of palm oil refining products that can be implemented so that the types of products distributed / exported are based on the source of the product and the purpose of delivery, the purpose of product delivery, the amount of product distribution that is distributed to minimizing distribution costs and maximizing total profit without neglecting the limitations of the actual system of export distribution networks of palm oil purification products using the NSGA-II approach (non dominated sorting algorithm II)[5].

2. Method
The study begins with an analysis of the entity of the export distribution network system of palm oil refining products using the Analytical system entity approach. The system entities analyzed are refinery factories, transportation modes, export ports, types of refined palm oil products and export destination countries [6].

In modeling a real system formulation into a mathematical model, the Mixed Integer Linear Programming approach is used. The model formulation that has been designed is as follows:

2.1. Constraints function modelling
The constraint function is needed so that the output obtained by the model can represent the actual system. The following are the existing functions in the export distribution of refinery products:

1) Number of Product Allocation by Refinery Factory
   a) Constraints to ensure the number of products allocated by all refineries does not exceed the total number of product requests for all foreign markets (exports) [2]. The mathematical formulation is as follows:
   \[ \sum_{i=1}^{I} \sum_{p=1}^{P} Q_{mip}^{D} \leq \sum_{k=1}^{K} B_{mk} \]  
   (1)
   b) Constraints to ensure the amount of product production allocated by all refineries in accordance with the capacity of the number of refinery factories [2]. The mathematical formulation is as follows:
   \[ \sum_{i=1}^{I} \sum_{p=1}^{P} Q_{mip}^{D} \leq \sum_{i=1}^{I} H_{mi}^{G} \]  
   (2)
   c) Constraints to ensure the number of product allocations allocated by all export ports does not exceed the total number of product requests for all foreign markets (exports) [2]. The mathematical formulation is as follows:
   \[ \sum_{p=1}^{P} \sum_{k=1}^{K} Q_{mpk}^{J} \leq \sum_{k=1}^{K} B_{mk} \]  
   (3)

2) Number of requests for export destinations
   Constraints to ensure that the number of product allocations supplied by refineries to all ports corresponds to the number of allocations exported to foreign markets [2]. The mathematical formulation is as follows:
   \[ \sum_{i=1}^{I} \sum_{p=1}^{P} a_{mip}^{D} Q_{mip}^{D} = \sum_{p=1}^{P} \sum_{k=1}^{K} a_{mpk}^{J} \cdot Q_{mpk}^{J} \]  
   (4)

3) Constraints of distribution channels from refinery factories to ports
   Constraints to ensure that there are always products that will be distributed from refinery factories to ports through optimal distribution channels [7]. The mathematical formulation is as follows:
   \[ \sum_{i=1}^{I} \sum_{p=1}^{P} a_{mip}^{D} \geq 1 \]  
   (5)

4) Constraints of distribution channels from ports to foreign markets
   Constraints to ensure that there are always products that will be distributed from ports to foreign markets through optimal distribution channels [8]. The mathematical formulation is as follows:
   \[ \sum_{p=1}^{P} \sum_{k=1}^{K} a_{mpk}^{J} \geq 1 \]  
   (6)
5) Constraints in total distribution costs
To ensure that the company will always use distributor services, the company is required to issue distribution costs. The mathematical formulation is as follows:

\[ X > 0 \]  
(7)

6) Total profit / profit constraints
To ensure that the company must make profit / profit. The mathematical formulation is as follows:

\[ Y > 0 \]  
(8)

7) Non-negative number constraints
To ensure that the value of the total allocation is not negative [2].

\[ Q_{mp}^D, Q_{mpk}^J \geq 0 \]  
(9)

2.2. Modelling purpose functions
The objective function of this mathematical model is the minimization of the total distribution cost (x) and the maximization of the total profit / profit (y) of the export of Refinery products [9].

Min \( x = \)

\[
\left[ \sum_{m=1}^{M} \sum_{i=1}^{I} \sum_{p=1}^{P} \sum_{v=1}^{V} a_{mp}^D \cdot C_{mpv}^D \cdot Q_{mpv}^D \right] + \\
\left[ \sum_{m=1}^{M} \sum_{p=1}^{P} \sum_{k=1}^{K} a_{mpk}^J \left( C_{mpk}^O + T_{mpk} \right) \cdot Q_{mpk}^J \right]
\]  
(10)

Max \( y = \)

\[
\left[ \sum_{m=1}^{M} \sum_{p=1}^{P} \sum_{k=1}^{K} E_{mp} \cdot a_{mpk}^J \cdot Q_{mpk}^J \right] - x \\
- \left[ \sum_{m=1}^{M} \sum_{i=1}^{I} F_{mi} + \sum_{m=1}^{M} \sum_{p=1}^{P} \sum_{v=1}^{V} V_{mpv} \cdot a_{mp}^D \cdot Q_{mp}^D \right]
\]  
(11)

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

**Table 1. Distribution network constraint function index.**

| Notation | Information |
|----------|-------------|
| \( m \) | Product type index (\( m, m \in 1,2,3, \ldots , M \)) |
| \( v \) | Index type of tank truck transportation (\( v, v \in 1,2,3, \ldots , V \)) |
| \( s \) | Ship transportation type index (\( s, s \in 1,2,3, \ldots , S \)) |
| \( i \) | Refinery factory index (\( i, i \in 1,2,3, \ldots , I \)) |
| \( p \) | Export port index (\( p, p \in 1,2,3, \ldots , P \)) |
| \( k \) | Export destination index (\( k, k \in 1,2,3, \ldots , K \)) |
The parameter notations used in the constraint function can be seen in Table 2.

**Table 2.** Distribution network constraint function parameters.

| Notation | Information |
|----------|-------------|
| $C_{ijpv}^R$ | Distribution costs from Refinery-i factories to export-p port destinations using v-tank truck transportation (IDR / Metric Ton) |
| $C_{pk}^O$ | Storage and handling costs from export-p port to export-k destination using ship-s transportation (IDR / Metric Ton) |
| $T_{mpk}$ | Product exit fee m on export-p port to export-k destination (IDR / Metric Ton) |
| $E_m$ | Product export price-m (IDR / Metric Ton) |
| $H_{mi}$ | Production capacity of m-products at Refinery-i (Metric Ton) |
| $B_{mk}$ | Number of m-product requests for export-k purposes (Metric Ton) |
| $V_{mi}$ | Variable production cost of products at Refinery-I factory (IDR / Metric Ton) |
| $F_{mi}$ | Fixed product production costs at Refinery-I factory (IDR / Metric Ton) |

Notation of objective function variables can be seen in Table 3.

**Table 3.** Distribution network decision variables.

| Notation | Information |
|----------|-------------|
| $a_{mp}$ | Binary numbers if the m-product or other product produced at the Refinery-i factory is distributed to the p-port of export received / rejected (binary) |
| $a_{mpk}$ | Binary numbers if the m-product in the p-export port is exported to the K-foreign market received / rejected (binary) |
| $Q_{mp}$ | Amount of product allocation m from Refinery-i factory to export-p port (Metric Ton) |
| $Q'_{mp}$ | Amount of product allocation m from export-p port to export-k destination (Metric Ton) |

Completion of Optimization Models Using NSGA-II Algorithm (non dominated sorting algorithm II) Model completion will produce outputs that are useful in determining decisions in exporting palm oil.
refining products. The completion of this optimization model is assisted by using Netbeans software. In the final stage of the research, the most optimum solution was found from a set of outputs from the run solution model. The method used in selecting the most optimum point is by using the LINMAP method [10].

3. Results and discussions

3.1. Distribution network system entity analysis
The export distribution network system of palm oil purification products produces optimum variables can be seen in Table 4 and Figure 1. In Figure 1 and Table 4, it can be seen that in order to produce a minimum distribution cost in order to obtain maximum profit, the distribution channel from the dominant refinery is opened to the Tanjung Priok port. As for the dominant export activities opened to India. For the number of allocations, the number of products allocated by the three dominant refinery factories was mostly allocated to Tanjung Priok with the number of export commodities as much as 16,341 MT for Stearin RBD products, 9,439 MT for RBD Olein products and 5,301 MT for PFAD products. More exports were allocated to India with 26,631 MT of export commodities for Stearin RBD products, 8,821 MT for RBD Olein products and 17,669 MT for PFAD products. Whereas for the types of products allocated to dominant export activities more allocated the Stearin RBD product type which was 31,079 MT.

3.2. Analysis of optimization model design
The mathematical model design optimization results for profit maximization and minimization of export activity distribution costs can be seen in Figure 2. From Figure 2 can be seen the results of the optimization model illustrates that the greater the distribution costs incurred by the company accompanied by the greater profit from the company's export activities. The large allocation of products to be exported results in the magnitude of the distribution costs, but with the increasing number of products allocated for export activities, the income earned by the company will be even greater, this will directly increase sales profit (export). To find the best solution point, calculation is done using the LINMAP approach. The optimum values of the optimization model in Figure 2, then calculated the smallest distance value from each of the optimization value points, the smallest distance between the ideal point of solution (axis (min x = 18,789,695,500; max y = 673,749,400,000)) to the value the optimum is based on Figure 2. The formulation used to calculate the distance value (Di) is the root of the total number of squares the difference between the optimum value of the x axis (Xi) minus the ideal value of the solution x (X) axis with the square of the difference between the optimum value of the y axis (Yi) minus the ideal value of the solution of the y (Y) axis.

\[ D_i = \sqrt{(X_i - X)^2 + (Y_i - Y)^2} \]  

The calculation example looks for the distance value for point 1 where, the value of X1 = IDR. 358,172,688,000; Y1 = IDR. 673,749,400,000; X = IDR. 18,789,695,500; Y = IDR. 673,749,400,000

\[ D_1 = \sqrt{(358,172,688,000 - 18,789,695,500)^2 + (673,749,400,000 - 673,749,400,000)^2} = IDR. 339,382,992,500 \]
Based on the results of the calculation of the entire optimum point, the optimum point that has the smallest distance (D) value is at point no. 5 with a distance value of IDR 166,251,802,176 located on the axis coordinates (X5 = IDR 150,548,677,000; Y5 = IDR 572,362,850,000) which means that by
using the optimization model, the total distribution costs to be paid is IDR 150,548,677,000 with a profit of IDR 572,362,850,000.

3.3. Analysis of soft-computing techniques
With soft-computing techniques, the time taken is very fast even in seconds to get the optimum solution by doing a very long iteration process. This is evident, using Netbeans software and NSGA-II approach when completing the search for the optimum solution of the mathematical model only takes 57 seconds as shown in Figure 3.

![Figure 3. Solution search time using soft-computing technique NSGA-II.](image)

3.4. Optimization model evaluation analysis
The optimization model optimization is needed when writing a program, this is proven by mathematical models that are not suitable so the program will only produce values that are not feasible and will even cause error results. In addition, the evaluation of the model will produce values that are in accordance with the constraints of the system (constraint) so that the output of the optimization model will produce realistic values and can represent the real system conditions.

3.5. Optimization model verification analysis
Verification on the model is done when the results of running the optimization model program produce an output error. When coding an optimization model program, what researchers do is to revise the coding input in the form of variables, parameter values, formulas and constraints of the optimization model. The results of running the optimization model program have resulted in the output of a variable decision variable that is feasible so that the optimization model has been verified (verified). The verification results are shown in Figure 4.

![Figure 4. Output feasible solution optimization model (verified).](image)

3.6. Optimization model analysis
Model validation is done to ensure that the designed optimization model has represented the real system. Researchers validate the optimization model by discussing with experts through the North Sumatra Indonesian Palm Oil Entrepreneurs Association (GAPKI) and the Medan Palm Oil Research Center (PPKS). The results of the model validation discussion with the expert are as follows.
1. Index validation and decision variables discuss the entities used in the index and decision variables in the form of palm oil export products from refinery refineries in Indonesia, transportation modes used, refinery plant locations in Indonesia, export ports that export palm oil refining products in Indonesia and countries that import Indonesian refined palm oil products. The results of the discussion with experts stated that the entities of each index and decision variables of the optimization model designed by the researchers have represented the real system of distribution network of export products from the refining of Indonesian palm oil (valid).

2. Validation of parameter values of the optimization model in the form of export prices of palm oil refining products, export duties, transportation costs and factory capacity. The results of discussions with experts stated that the parameter values obtained from trusted sources are in accordance with the data in the field (valid).

3.7. Optimization model advantages analysis
The advantages of the optimization model that researchers have designed are as follows:
1. Using Entity's analytical System approach, an optimization model (mathematical model) that has been designed can represent the actual system without losing the actual system complexity element (NP-Hard complex problem). The complexity of the system in question is a matter of uncertainty / uncertainty, problem estimation / approximation, the problem of not persistence / imprecision and the problem of partial truth.
2. With the soft-computing technique approach the system complexity problem can be solved in a short time. The search for the optimum solution only takes a matter of seconds, if it is done conventionally it will take days to months.

3.8. Deficiency analysis model optimization
The advantages of the optimization model that researchers have designed are as follows:
1. The optimization model has not estimated transport mode capacity, product delivery time, penalty fees due to delays in product delivery, distance of product delivery from source to destination and cost per product delivery distance from source to destination. This is because researchers use logistics calculators to determine costs in activities product delivery.
2. The absence of studies on the value of crossover and mutation probability in soft-computing techniques so that it cannot be ascertained whether the optimum solution search time that has been done when running the optimization model has been maximal or not.

4. Conclusions
The conclusions obtained from this study are:
- Distribution network system entity refinery export refinery products consist of Refinery Plant, Distributor, Exporter and Foreign Market. The analyzed system produces Indexes, Parameters, decision variables and Research Assumptions.
- Formulation of mathematical model optimization of multiple distribution goals Export distribution of refined products Palm oil is converted into Mix Integer Linear Programming with the purpose of minimizing Distribution Costs (x) and profit maximization (y).
- The implementation of the model using the NSGA-II is done with the Java programming language from the MOEA Framework written on Eclipse Oxygen.

The mathematical model is evaluated by a case sample and produces an optimal solution with a solution search time of 57 seconds with the results of the first objective function, namely the Minimization of Distribution Costs (x) of IDR 150,548,677,000 and the value of the second objective function is Profit Maximization (y) of IDR 572,362,850,000. The model has been verified by producing a feasible solution from the case sample and has been validated through discussions with experts in the North Sumatra Indonesian Palm Oil Association (GAPKI) and the Medan Palm Oil Research Center (PPKS).
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