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Flexible Supply Chain Network Design For CPO Derivatives

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ABSTRACT

The crude palm oil (CPO) industry is one of the leading industrial sectors in Indonesia. The diversification of derivative products from the CPO refinery is very high (multi-product). The challenges of inefficiency in the distribution network of refined CPO products include multi-product, transportation distances, transportation costs, uncertainty in the supply chain, and traceability of products sent, volatile demand and having to adjust production volumes without incurring significant costs. actors and is a challenge that researchers also face. Therefore supply chain flexibility is a problem that arises in practice. The purpose of this research is to design a flexible supply chain network of CPO refinery products. Metaheuristic algorithm Genetic Algorithm (GA) is used in solving optimization challenges. Distribution network system entities are analyzed and then made into a mathematical form of Mixed Integer Linear Programming. Furthermore, the model was built with the help of the GA algorithm which was developed in the Java programming language using the MOEA Framework. The verification and validation of the model was carried out with a case study in the CPO refinery industry. The optimization results are evaluated for twelve periods to see the flexibility of the supply chain network design model that has been made the minimum cost for twelve simulation periods is Rp. 636,675,671 in the 9th period and the flexibility of the model for twelve periods is considered flexible because the model is able to meet demand with network utility above 100% in 8 simulation periods.

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1. INTRODUCTION

The palm oil industry is one of the leading industrial sectors in Indonesia. Data from Palm Oil Analytics in 2016 shows that Indonesia is in the first position as the largest producer of crude palm oil (Crude Palm Oil, CPO) in the world, which is 34.52 million tons (Essential Palm OSupply il Statistics 2016). Indonesia's geographical suitability is one of the triggers for the development of oil palm plantations (Hadiguna 2016).

The development of the CPO-producing industry provides great benefits for the CPO refining industry. CPO is used as the main raw material for purified derivative products such as oleofood products (cooking oil, margarine, shortening) and oleochemicals (fatty acids, fatty alcohol, glycerine)

(Hadiguna 2016). Oleofood products are one of the food commodities that are often used by the community not only for household needs but also for industrial needs. According to a 2016 Central Bureau of Statistics survey, 58.05% of cooking oil production is destined for domestic consumption (Central Bureau of Statistics 2016). This indicates Indonesia's potential in developing the CPO refining industry. The high diversification of CPO derivative products (multi-product) is one of the challenges for the CPO refinery industry.

The Center for Palm Oil Research (PPKS) Medan stated that there is no scientific model that can be strategic level decision support to determine the number of products distributed and the selection of distribution flows that can solve the challenges faced. This complex problem in the distribution network of refined CPO products takes into account the challenges of multi-product, decisions on the number of products to be distributed and the selection of distribution channels (Ibrahim, Dogan. 2016).

Rapid changes in climate and irresponsible human consumption behavior have led to scarcity of natural resources as well as natural disasters. The high degree of environmental uncertainty has attracted the attention of operations researchers and supply chain management. Therefore, supply chain network design is considered very important among various operations and supply chain management strategies to address one of the greatest human concerns of this century noting in one of his scientific works that supply chain design problems are still undeveloped and advocating for more advanced work. comprehensive approach to the development of a supply chain network design that is flexible and sensitive to change. (Melnyk et al. 2014).

Supply chain flexibility is the supply chain's ability to quickly respond to changing customer requirements without compromising performance (Kumar et al., 2006; Zhang et al., 2002). In addition, the issue of supply chain flexibility has been discussed extensively in the literature, particularly with regard to the measurement and evaluation of supply chain flexibility. An agile supply chain network includes companies such as suppliers, production centers and distribution centers that are legally separated but operating requirements are linked together by material flow and feedback information feedback. Flexible supply chain network is focused on increasing responsiveness and flexibility and being able to respond and react quickly and effectively to market changes (Lin et al., 2006). In other words,

Flexibility in supply networks with respect to uncertainty, has been a challenge for researchers over the last few years. Highly flexible supply chains are characterized by high-performance dynamic supply chain processes that are able to maintain stable performance, even when changing conditions lead to greater flexibility requirements that must be met by the entities involved (Das & Abdel-Malek, 2003). As a result, the capability of dynamic supply chain processes to provide needed products quickly and at low cost while addressing more demanding and changing requirements is a strong indicator of flexibility.

Therefore, supply chain flexibility is an emerging problem in practice (Gunasekaran et al., 2014). As a result, many scientific approaches have been proposed to measure the flexibility of the entire supply chain. However, assessing flexibility at the supply chain level is very difficult. The reason is that the supply chain is a complex system, influenced by the inherent internal and external uncertainties arising from intra- and inter-organizational relationships (Fayezi et al. 2014).

2. RESEARCH METHOD

In this study, an Entity-Based System Analysis was conducted to determine the system entities in the distribution network of CPO purification products, namely cooking oil, margarine and shortening products. This is done by looking at previous research and survey data.

The results of the 2016 Cooking Oil Commodity Trading Distribution survey conducted by the Central Statistics Agency (BPS) stated that almost half of Indonesia's total cooking oil production was exported abroad and the rest was sold to other business institutions, both at the level of wholesalers and retailers. directly to the final consumer. In terms of trade, the distribution chain of cooking oil in Indonesia shows the complete distribution pattern of cooking oil commodity trade in Indonesia is presented in Figure 1.

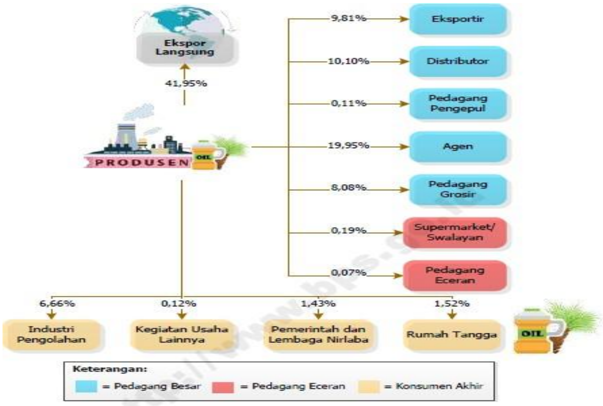


Figure 1. Cooking Oil Production Sales Pattern in Indonesia

3. RESULTS AND DISCUSSIONS

3.1 Analysis and Discussion of Model Simulation Results

The simulation results with GA period 1 show that all requests have been fulfilled by distribution channels such as the following where requests from distributors 1,2, and 3 are fully fulfilled by producers 1,2, and 3. Wholesaler 2 requests are fulfilled by distributors 1 and 3. Wholersaler requests 1 fully fulfilled by distributors 3 and 1. Wholesaler 3 requests are fulfilled by distributors 1 and 2. Retailer 1 demand is fulfilled by Wholesalers 1,2 and 3. Retailer 2 demand is fulfilled by Wholesalers 2 and 3. Retailer 3 demand is fulfilled by wholesalers 2 and 3 With the resulting total distribution costs are Rp. 658,436,086.

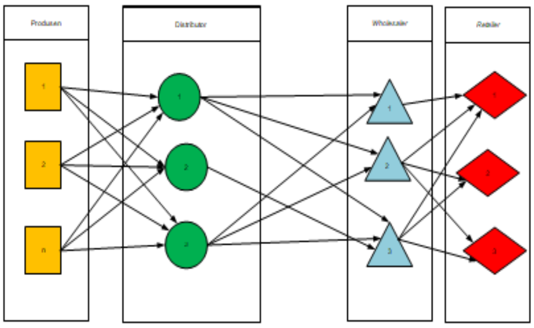


Figure 2. Flexible Supply Chain Network Simulation Results Period 1

The simulation results with GA period 2 show that all requests have been fulfilled by distribution channels such as the following where requests from distributors 1,2, and 3 are fully fulfilled by producers 1,2, and 3. Wholesaler 2 requests are fulfilled by distributors 2 and 3.

Wholersaler requests 1 fulfilled by distributors 3 and 1. Wholesaler 3 demand fulfilled by distributor 1 and 2. Retailer 1 demand was fulfilled by Wholesaler 2 and 3. Retailer 2 demand was fulfilled by Wholesaler 1. Retailer 3 demand was fulfilled by wholesaler 1 with the total distribution cost generated is Rp. 645,832,904.

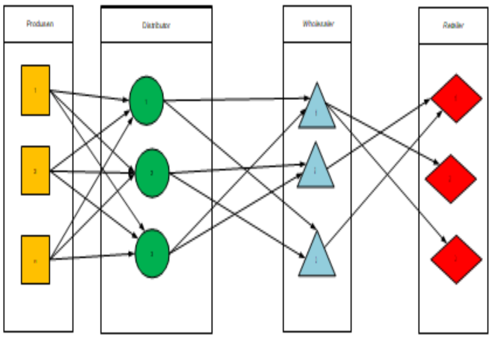


Figure 3. Flexible Supply Chain Network Simulation Results Period 2

The simulation results with GA period 3 show that all requests have been fulfilled by distribution channels such as the following where requests from distributors 1,2, and 3 are fully fulfilled by producers 1,2, and 3. Wholesaler 2 requests are fulfilled by distributors 1, 2 and 3. Wholersaler 1 requests are fulfilled by distributors 3 and 1. Wholesaler 3 requests are fulfilled by distributors 1 and 2. Retailer 1 requests are fulfilled by Wholesalers. . 646,204,932.

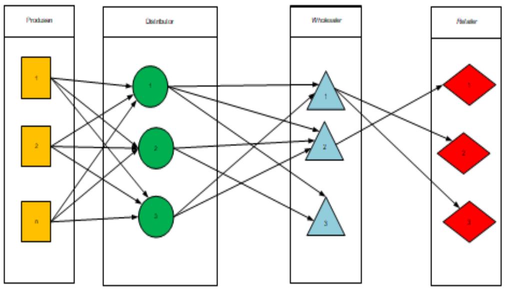


Figure 4. Flexible Supply Chain Network Simulation Results Period 3

The simulation results with GA period 4 show that all requests have been fulfilled by distribution channels as follows where requests from distributors 1,2, and 3 are fully fulfilled by producers 1,2, and 3 Wholesaler 2 requests are fulfilled by distributors 1 and 2. Wholersaler 1 requests are fulfilled by distributors 3 and 2. Wholesaler 3 demand is fulfilled by distributor 1 and 3. Retailer 1 demand is fulfilled by Wholesaler 2 and 3. Retailer 2 demand is fulfilled by Wholesaler 2 and 3. Retailer 3 demand is fulfilled by wholesaler 1. with total distribution costs generated is Rp. 652,305,858

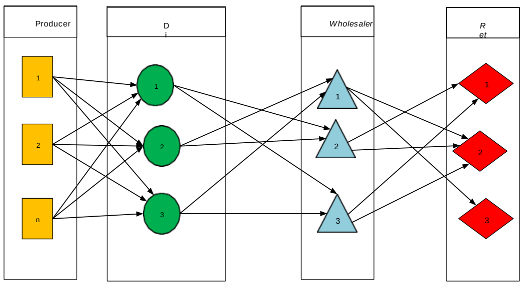


Figure 5. Flexible Supply Chain Network Simulation Result for Period 4

The simulation results with GA period 5 show that all requests have been fulfilled by distribution channels as follows where requests from distributors 1,2 and 3 are fully fulfilled by producers 1,2, and 3 Wholesaler 2 requests are fulfilled by distributors 1 and 2. Wholersaler 1 requests are fulfilled by distributors 3 and 2. Wholesaler 3 demand is fulfilled by distributor 1 and 3. Retailer 1 demand is fulfilled by Wholesaler 2 and 3. Retailer 2 demand is fulfilled by Wholesaler 2 and 3. Retailer 3 demand is fulfilled by wholesaler 1. with total distribution costs generated is Rp. 641,977,867.

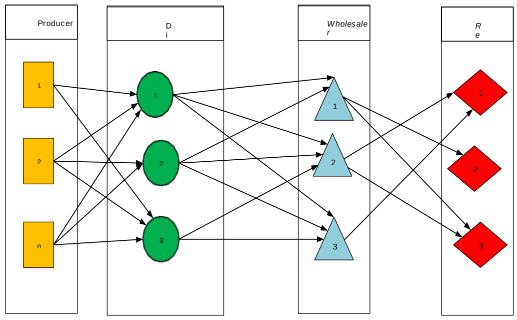


Figure 6. Flexible Supply Chain Network Simulation Results for Period 5

The simulation results with GA period 6 show that all requests have been fulfilled by distribution channels as follows where requests from distributors 1,2, and 3 are fully fulfilled by producers 1,2, and 3 Wholesaler 2 requests are fulfilled by distributors 1 and 2. Wholersaler 1 requests are fulfilled by distributors 3 and 2. Wholesaler 3 demand is fulfilled by distributor 1 and 3.

Retailer 1 demand is fulfilled by Wholesaler 2 and 3. Retailer 2 demand is fulfilled by Wholesaler 2 and 3. Retailer 3 demand is fulfilled by wholesaler 1. with total distribution costs generated is Rp. 644,906,676.

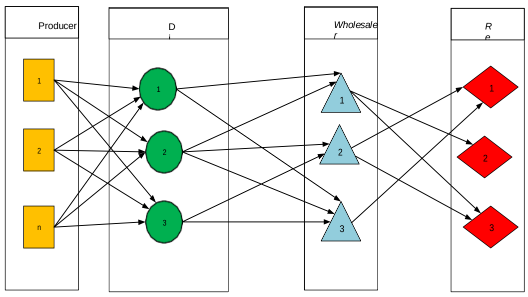
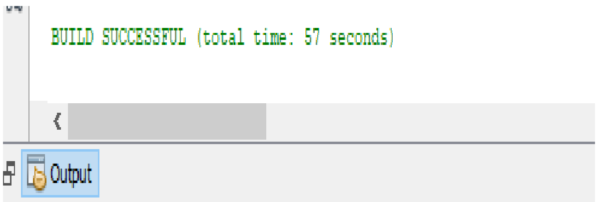


Figure 7. Flexible Supply Chain Network Simulation Results for Period 11

The simulation results with GA period 12 show that all requests have been fulfilled by distribution channels such as the following where requests from distributors 1,2, and 3 are fully met by producers 1, 2, and 3. Wholesaler 2 requests are fulfilled by distributors 1 and 2. Wholersaler 1 requests are fulfilled by distributors 3 and 2. Wholesaler 3 requests are fulfilled by distributors 1 and 3. Retailer 1 requests are fulfilled by Wholesalers 2 and 3. Retailer 2 requests are fulfilled by Wholesalers 2 and 3. Retailer 3's demand is fulfilled by wholesaler 1. with a total distribution cost of Rp. 646,765,877.

3.2 Soft Computing Engineering Analysis

The soft-computing technique is intended to obtain the optimum solution from a very large number of solution populations so that for manual processing it is impossible to do because it requires very many iterations and a very long calculation completion time from a mathematical model. With this technique, the time required is very fast, even in seconds to get the optimum solution by carrying out a very long iteration process. This is proven, by using GA the completion time of finding the optimum solution from the mathematical model only takes 57 seconds as shown in Figure 8.



Source: NetBeans 8.1

Figure 8. Solution Search Time Using Soft-Computing Techniques GA

a. Sensitivity Analysis

Parameter $C_{i,m,n}^{Trans\ P-D}$ has the greatest influence on the simulation output generated every 1% increase the output will increase by 0.55%. For parameters $C_{i,m,n}^{Trans\ D-W}$ every 1% increase in output will increase by 0.21%. For parameters $C_{i,m,n}^{Storage\ D}$ a 1% increase in output will increase by 0.12%. For parameter $C_{m,n}^{Storage\ W}$ s a 1% increase in output will increase by 0.09%. For parameters $C_{i,m,n}^{Trans\ W-R}$ a 1% increase in output will increase by 0.02%.

b. Supply Chain Network Flexibility Analysis

Table 1. Flexibility Analysis

Period	demand	Supply Capacity	Utility (%)
1	41813	48165	86,812
2	32778	48165	68.0536

Table 2. Flexibility Analysis (Continued)

Period	demand	Supply Capacity	Utility (%)
5	50136	48165	104,092
6	47691	48165	99.0159
7	50423	48165	104,688
8	49286	48165	102.327
9	50251	48165	104,331
10	48178	48165	100,027
11	49075	48165	101.889
12	50982	48165	105,849

The model is able to respond to requests when network utility is above 100% this means that the design model is flexible. But how can the network respond to demand above its supply capacity.

This indicates that actors may do overtime work in order to meet consumer demand. By doing overtime work, the supply capacity of the network will increase which results in demand being met, but assigning workers to work overtime will cost higher. Manufacturers can also subcontact to meet demand, this is more practical than having to do overtime work so that costs can also be minimized.

c. Model Verification

In doing the modeling, there are several obstacles so that an error occurs when running the program. This is due to the researcher's errors when typing coding and errors in inputting parameters so that the results obtained are not feasible. Researchers verify the model by checking and revising errors when modeling. After the model is checked and the errors found when making the model have been corrected, the model produces a feasible solution so that it can be said that the model has been verified.

d. Model Validation

To ascertain whether the designed model already represents the real situation, the researchers validated the model to experts through the Indonesian Palm Oil Association (GAPKI) North Sumatra, the Palm Oil Research Center (PPKS) Medan and a Public Appraisal Service Consultant who often handles problems in the oil palm sector. When discussing with experts, the researcher validated the model to ensure that the model was in accordance with the real system. Experts provide criticism and suggestions regarding the model and system entities contained in the model. According to the expert, the designed model has represented the real situation so that it can be said that the model has been validated.

4. CONCLUSION

The elements of the distribution network system for refined palm oil (CPO) products consist of producers, distributors, wholesalers and retailers. The decision variables in this study are the number of product shipments, and distribution channels. The parameters in this study are demand, warehouse capacity, product storage costs for each actor, shipping costs, and inventory. The assumptions and limitations of this research are that no products are returned and in one distribution all three types of products are allocated.

The formulation of the mathematical model is carried out using the Mixed Integer Linear Programming method with the objective function of minimizing costs and model constraints taking into account inventory, demand, warehouse capacity, number of product shipments, and distribution channels.

The use of Genetic Algorithm to obtain the optimum solution only takes 57 seconds with a reduced cost of Rp. 369,107,614.

The optimization model that has been formulated is tested in cases where the results are measured by the variables of the number of products distributed, distribution flow in the supply chain network, minimum cost (Z), and network flexibility. The design is flexible because it is able to meet existing demand with utilities above 100% for 9 periods at a cost of Rp. 630.892.386.

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