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Alamat Penerbit :
Fakultas Teknologi Industri - ITS
Gedung Rektorat ITS Lantai III
Kampus ITS Sukolilo - Surabaya
Telp. (031) 5947843, 5922938
Fax. (031) 5947843, 5933228
E-mail : fti@its.ac.id

EDITORIAL

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Redaksi

INDUSTRI, Jurnal Ilmiah Sains dan Teknologi, diterbitkan setiap bulan Februari, Juni dan Oktober oleh Fakultas Teknologi Industri ITS. Penanggung Jawab : Dekan FTI - ITS. Terbit pertama Oktober 2002. Redaksi mengundang para peneliti, praktisi dan profesional di bidang ilmu teknik, khususnya Teknik Mesin, Teknik Elektro, Teknik Kimia, Teknik Fisika, Teknik Industri dan Teknik Material untuk menyumbangkan hasil penelitiannya ke dalam jurnal ini. Bagi para pembaca yang berminat untuk mendapatkan terbitan jurnal INDUSTRI secara teratur, dapat menghubungi redaksi.

YANDRA ARKEMAN
9/4/2012

Daftar Isi

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FUZZY INVENTORY MODELING OF CRUDE PALM OIL IN THE PORT BULK TANK

Machfud[1], Eriyatno[1], Ani Suryani[1], Yandra Arkeman[1], Rika Ampuh Hadiguna[2]
[1]Department of Agroindustrial Technology, Faculty of Agricultural Technology
Bogor Agricultural University (IPB), Darmaga, Bogor, Indonesia
[2]Department of Industrial Engineering, Faculty of Engineering, Andalas University
Limau Manis, Padang, Indonesia
email: mfd@indo.net.id; hadiguna05@yahoo.com

Abstract: *This paper aims to develop a model for inventory optimization of crude palm oil by applying the economic order quantity (EOQ) and the fuzzy theory. The used defuzzification method is the signed distance method. Model development was conducted by, first, re-formulating the EOQ basic model. The model development was implemented in terms of decision support systems with the inventory optimization and sales forecast of crude palm oil as the model basis, whereas the parameters of cost, demand bias and past sales data as the data basis. Defuzzification was used as the knowledge basis. The study showed that the optimal quantity measurement of the fuzzy EOQ was always less than crisp EOQ model. The produced decision support system can support the decision-makers in planning and control the supply operational to the port.*
Keywords: *inventory, EOQ, fuzzy, decision support system, crude palm oil*

Abstrak: *Makalah ini bertujuan mengembangkan model untuk optimasi persediaan minyak sawit kasar dengan menerapkan* economic order quantity *(EOQ) dan teori* fuzzy. *Metoda defuzzifikasi yang digunakan adalah* signed distance. *Pengembangan model dilakukan dengan terlebih dahulu melakukan formulasi ulang dari model dasar EOQ. Pengembangan model diwujudkan dalam bentuk sistem penunjang keputusan dengan basis model adalah optimasi persediaan dan prakiraan penjualan minyak sawit kasar, sedangkan basis data adalah parameter-parameter biaya, bias permintaan dan data masa lalu penjualan. Basis pengetahuannya adalah defuzzifikasi. Hasil studi menunjukkan bahwa ukuran kuantitas optimal EOQ* fuzzy *selalu lebih kecil dibandingkan model EOQ* crisp. *Sistem penunjang keputusan yang dihasilkan dapat membantu pengambil keputusan dalam perencanaan dan pengendalian operasional pasokan ke pelabuhan.*
Kata kunci: *persediaan, EOQ,* fuzzy, *sistem penunjang keputusan, minyak sawit kasar*

INTRODUCTION

In the Agroindustrial supply chain system of crude palm oil (CPO), inventory policy is one of the major concerns. Inventory is not only beneficial for maintaining the service level, but also for providing consequences to the total cost of supplies. Problem of crude palm oil inventory, that is quite important, is determining level of inventory in the port bulk tank. The factory unit that processes the fresh fruit bunches into crude palm oil will send the supplies to the port based on demand.

The arisen complexity of inventory problems is triggered by demand fluctuation, product availability in the processing unit and harvest season in the palm field unit. Specifically, the right perspective should be placed to improve the effectiveness of supply chain management. Inventory management in the bulk tank should not ignore the fuzzy condition in the decision-making process.

Business environment that is very competitive and fluctuating has to be considered correctly by the decision-makers. Demand forecast can not much longer be defined in the form of crisp values in the business situation with fluctuating and competitive demand. Fuzzy form of demand is represented in normal demand number, high or low. Fuzzy state will trigger the loss of sales and revenue risk so that requires an appropriate approach to handle. One of the solutions is by applying the fuzzy techniques.

This study aimed to develop a mathematical model and to design a decision support system for crude palm oil inventory control by applying the economic order quantity (EOQ) with fuzzy demand conditions. EOQ model is proven to be quite effective in its implementation for inventory control in various fields. Implementation is carried out through the re-formulation of the EOQ basic model. Model development is implemented in the form of decision support systems. System approach in the decision-making, which is known as decision support systems, is intended to describe system elements in detail so that system can support managers in decision-making process (Eriyatno 2003).

Scope of supply chain system which is discussed in this study is interaction between factory plant and port bulk tank. Inventory control policy of crude palm oil is focused in port bulk tank to obtain optimal order quantity. Real situation is modeled as mathematical model. The benefit of this study is the software that will help the decision-makers such as plant managers and district general managers in coordinating to maintain the optimal inventory levels.

LITERATURE REVIEW

Inventory models that apply fuzzy theory have been mathematically developed. Lee and Yao (1998) discussed economic production quantity (EPQ) model with fuzzy demand and fuzzy production using triangular membership function. The discussion substance was the computation scheme by applying centroid defuzzification method.

Lee and Yao (1999) also discussed the EOQ model with fuzzy ordering quantity and fuzzy total inventory cost using centroid defuzzification method. The similarity between these two models was the application of centroid defuzzification method and triangle membership functions, while the difference was the applied inventory model.

Chen and Hsieh (2000) developed a principal functions defuzzification method that could be applied to trapezoidal and triangle membership functions. The discussion was still focused on the mathematical explanation that was intended to produce computing scheme only. The application of the model development was the inventory EOQ model.

Syed and Aziz (2007) applied the signed distance method to the EOQ model with ordering cost and storage cost of fuzzy conditions. The comparison result showed that the ordering quantity of the fuzzy model was larger than the crisp model.

Yao and Chiang (2003) compared the centroid defuzzification and signed distance methods on the EOQ model with fuzzy total inventory cost and fuzzy storing cost. The comparison results showed that the signed distance method gives better result.

The direction of further model development was to consider various conditions in inventory policy with fuzzy conditions. Kao and Hsu (2002) considered the stock-out cost with fuzzy conditions demand. Defuzzification using Yager method for ranking fuzzy numbers thus it was obtained the smallest total inventory cost.

Chiang et al. (2005) developed a model that considered the stock out cost with all fuzzy conditions inventory parameters. The used membership function was the triangular with defuzzification using the signed distance method. The focus of the discussion was only on the computational scheme to improve the accuracy of the calculation results.

Chen et al. (2007) developed an EPQ inventory model by considering that there were inferior products and fuzzy conditions on demand, the cost of storage and preparation costs. The used defuzzification method was the principal function with the trapezoidal membership function.

The completion techniques for inventory model which is containing the fuzzy condition on model component were also developed. Gao and Feng (2006) developed an inventory model with fuzzy condition on demand and considering the product sales price discount rate. A very complex mathematical formulation was solved by assigning a framework that consists of hybrid intelligent algorithm and dynamic program. Kumal and Raju (2008) developed an inventory model that considered the stock out cost and product damage. The model was formulated with two objectives, those were revenue maximization and minimization of waste product cost. The developed model solution techniques were the weighted non-linear fuzzy programming, fuzzy additive goal programming and the integration of those two techniques. The discussion was aimed to compare those solving techniques without concluding which completion technique was better. Taleizadeh et al (2009) developed the inventory model with fuzzy conditions on demand. The model solving technique uses particle swarm optimization. This solving technique was also used by Xiaobin et al. (2007) for inventory model with fuzzy conditions preparation cost and storage cost.

Inventory model development in paper industries can be found in the paper discussed by Björk (2008). The developed EPQ model aimed to get the optimum supply cycle time. Fuzzy condition was defined in the inventory cycle time with triangular membership function. Model finishing was carried on analytically.

Not so many inventory models that were developed based on real conditions of an industry, including the crude palm oil agroindustry. Model development that is described mathematically will complicate its application in practical. Inventory mathematical model loading into the model base in a decision support system will provide specific appropriate values for managers or decision makers.

RESEARCH METHOD

This study was applying a system approach that is solution which begins with identification of needs until resulting an operation of the system that is considered to be effective (Eriyatno 2003).

This study was conducted on a plantation company in East Kalimantan. Data collected through in depth interviews to obtain information regarding decision making process in inventory control at the port. The collected secondary data consisted of the realization reports of crude palm oil sales and the costs associated with inventory management.

This study was carried out based on several stages which were systematically conducted as follows:

First, studying inventory system of crude palm oil by observation and in-depth interviews. Second, estimating crude palm oil sales based on data from last 60 months. Third, determining the quantity of crude palm oil inventory at the port by accommodating the demand fuzzy condition. Fourth, designing a decision support system by combining the database, model base and knowledge base. Finally, model verification by checking the logic, the compatibility between conceptual and the work of computer program and model validation using mathematical and face validity techniques.

RESULT AND DISCUSSION

Model Development

The elements of the inventory system of crude palm oil in the port bulk tank consists of crude palm oil demand (d) from the port, that is an effort to meet the sales plan or shipment, and ordering quantity (q), that is the amount of economic supply to the port. High and low number of request is defined as fuzzy query ($\tilde{d}$) with triangular membership function. The involved cost components are ordering cost (k), storage cost (h) of product in the bulk tank, and transportation cost per kilogram (c) of crude palm oil from the factory plant to the port. Total inventory cost or TC (q) is the sum of all associated costs, as follows:

$$TC(q) = \left(c \otimes \tilde{d}\right) \oplus \left(\frac{k \otimes \tilde{d}}{q}\right) \oplus \frac{hq}{2} \qquad (1)$$

Equation (1) is basic equation of EOQ model that show the inventory total cost (Chien and Shieh 2000, Chiang *et. al.* 2005) and it is modified with demand query ($\tilde{d}$) in fuzzy number. Demand value that is not firmly expressed is represented in the form of fuzzy numbers. If the demand is symbolized by $\tilde{d}$ in the form of triangular fuzzy numbers, then there will be a difference of D that is determined by decision makers based on their knowledge and experience. The D values will contribute to the demand value difference of or , where d is a known number from the previous forecast. Fuzzy value of can be written as follows:

$$\tilde{d} = (d - \Delta_1, d, d + \Delta_2) \qquad (2)$$

Total inventory cost will be in the form of fuzzy where TC (q) is in condition where and . The values of H_1, H_2 and H_3 can be formulated:

$$H_1 = TC(q) - c\Delta_1 - \frac{k\Delta_1}{q} \qquad (3)$$

$$H_2 = cd + \frac{kd}{q} + \frac{hq}{2} \qquad (4)$$

$$H_3 = TC(q) + c\Delta_2 + \frac{k\Delta_2}{q} \qquad (5)$$

Defuzzification can be done using signed distance method in accordance with the basic formula (Yao and Chiang 2003) with the following results:

$$d(TC(p),0) = cd + \frac{kd}{q} + \frac{hq}{2}$$

$$+\frac{1}{4}\left\{c(\Delta_2 - \Delta_1) + \frac{k(\Delta_2 - \Delta_1)}{q}\right\} \quad (6)$$

Optimal value of ordering quantity q^* is obtained by getting the first derivative of Equation 6. Conditions that need attention are and .

$$\frac{k\{4d + (\Delta_2 - \Delta_1)\}}{4q^2} = \frac{h}{2}$$

$$q^* = \sqrt{\frac{k(4d + \Delta_2 - \Delta_1)}{2h}} \quad (7)$$

In the case of demand in firmly form or in exact number then the elements of difference D_1 and D_2 are equal to zero or $D_1 = D_2 = 0$. Equation 7 for condition $D_1 = D_2 = 0$ will be the equation from the firm EOQ basic model. The total inventory cost by considering fuzzy condition demand is represented as follows:

$$TC(q^*) = cd + \frac{kd}{q^*} + \frac{hq^*}{2}$$

$$+\frac{1}{4}\left\{c(\Delta_2 - \Delta_1) + \frac{k(\Delta_2 - \Delta_1)}{q^*}\right\}$$

$$TC(q^*) = cd + \frac{1}{4}c(\Delta_2 - \Delta_1)$$

$$+\frac{1}{2}\sqrt{2kh(4d + \Delta_2 - \Delta_1)} \quad (8)$$

If the equation of fuzzy total inventory cost is compared to the total inventory cost of firm EOQ model, it is differentiated by elements Δ_1 and Δ_2. If $\Delta_1 = \Delta_2 = 0$, then it will go back into firm EOQ.

Optimal point which has been obtained can be proven by examining the second derivative of the total inventory cost function.

$$\frac{d^2TC(q)}{dq^2} = \frac{k\{4d + (\Delta_2 - \Delta_1)\}}{8q^3} \quad (9)$$

$\frac{d^2TC(q)}{dq^2} > 0$ or always be positive as proof that q^* is the optimal value, so that it will produce the minimum total inventory cost. Fuzzy value of d for the total inventory cost function will give a positive value with the following explanation:

$$4d + \Delta_2 - \Delta_1 = 3d + \Delta_2 + (d - \Delta_1) \quad (10)$$

Procedure to determine the value of supply to the port bulk tank consists of two basic steps, those are: setting the bias value of sales, and setting the value of D_1 and D_2 based on the opinions of decision makers among the authorities of bulk tank management at the port. Then, preparing the data that is associated with shipping cost (c), ordering cost (k), the storage cost (h) and sales forecast (d).

Value of sales bias will be the database while the cost parameter will be the input in the interface. After these two kinds of data are available, the calculation of economic supply value and the total inventory costs can be carried out based on the formula that has been formulated.

A decision support system of crude palm oil inventory in the port bulk tank consists of the model base and database. The model base consists of optimization of inventory, total cost of inventory and defuzzification technique. The database is the parameters of cost, demand bias and sales or demand forecasting data that can be updated as circumstances change in the company. Decision support system is designed to plan the amount of supplies to the port during one year in monthly basis. Configuration of model can be seen in Figure 1.

Verification was conducted by tracing the running program first. If the entire line of program code was successfully executed according to the logic then program would be considered successful. Next examination was the examination of result or output of the computer program. A good model would produce solution that met to the model requirements. If the completion of the program indicated any error and did not work according to the defined logic, then it would be repaired. Verification process had been carried out and model was able to work in accordance with the assumed logic and conditions.

Validation aimed to obtain a match that the model already contained all of the elements, events and relations of the real system. The applied *Face validity* technique was formulating the fundamental questions regarding the usefulness and accuracy of model prediction that involved the participation of practitioners and academics separately. The model was considered as valid because it represented the basic elements of the crude palm oil inventory system and was able to predict well the overall key system operation.

A Case Study

Determination of inventory can be determined based on the sales forecast. Forecast made for the next 12 months. The goal was to know the sales forecast every month that would be the input in determining the quantity of the economic supply each month. Table 1 contains the results of crude palm oil sales forecasting (d).

Other inputs that are required are parameters of cost and demand interval limit. Data of inventory cost for k = IDR 14,466,684 , c = Rp 54,000 per ton and h = IDR 9,070 per ton per month. The limits of demand value that are accommodated by fuzzy parameter are obtained based on the opinion of the decision makers, those are $\Delta_1 = 0.1d$ and $\Delta_2 = 0.05d$. Parameter values are inputted to the software interface as shown in Figure 2.

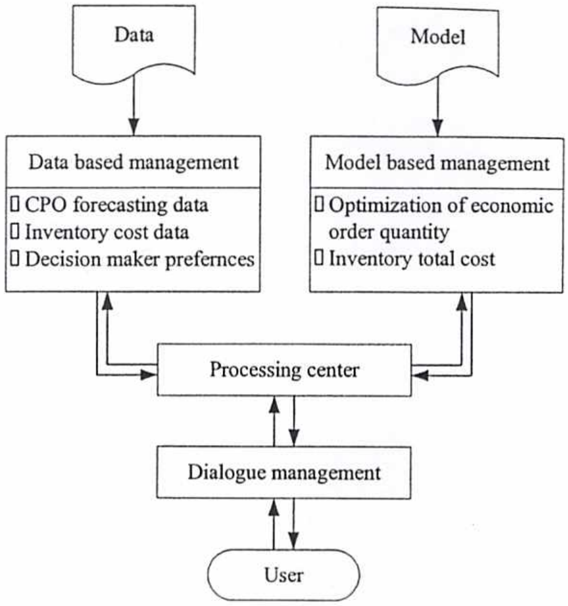

Figure 1. Planned decision support system

The result of inventory optimization by determining the quantity of the economic supply from factory plant to the port that was produced by the software can be seen in Table 1.

Results from the model showed that the amount of the economic supply quantity and demand forecast are almost equal. Supply cycle time approached one period. A supply planning period

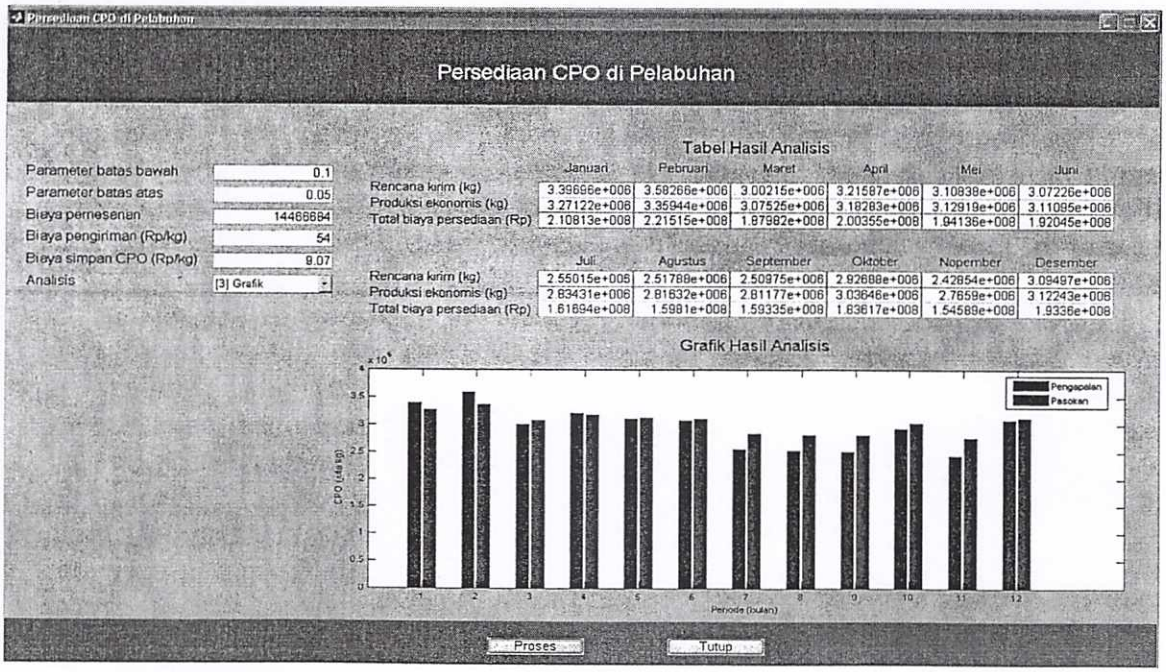

Figure 2. Model interface

in this study was one month. This could mean that delivery to the port was carried out one times only.

The amount of the supply quantity will be influenced by the value of Δ_1 and Δ_2 as a parameter determining the demand interval length. Value of supply quantity will be different if Δ_1 and Δ_2 are modified. The existence of the software can be utilized by decision makers to analyze several scenarios of inventory policies. Scenarios can be defined in three categories, namely optimistic, moderate and pessimistic.

Table 1. Economic Supply Quantity (ton)

Period	Supply	Demand		
		Low	Normal	High
January	3,271	3,227	3,396	3,736
February	3,359	3,403	3,582	3,940
March	3,075	2,852	3,002	3,302
April	3,182	3,055	3,215	3,537
May	3,129	2,952	3,108	3,419
June	3,110	2,918	3,072	3,379
July	2,834	2,422	2,550	2,805
August	2,816	2,391	2,517	2,769
September	2,811	2,384	2,509	2,760
October	3,036	2,780	2,926	3,219
November	2,765	2,307	2,428	2,671
December	3,122	2,940	3,094	3,404

Optimistic scenario is the tendency that demand will be greater than expected. The value of parameter D_2 will be greater than D_1. Pessimistic scenario is the tendency that demand will be less than normal demand. The value of parameter D_1 will be greater than D_2. The normal scenario is the condition considered by decision-makers that demand more or less in the same in intervals. The value of parameter D_2 is equal to D_1. The result of analysis on those three scenarios can be seen in Figure 3.

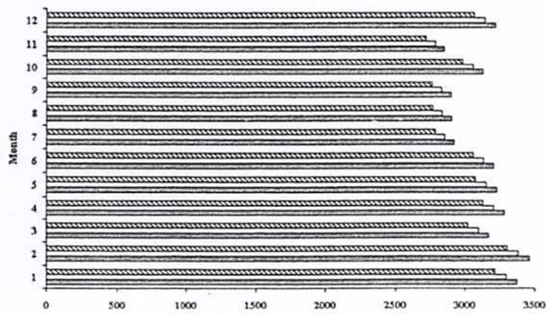

Figure 3. The q^* value based on scenario

Simulation on the influence of the demand interval in the three scenarios on the value of q^* indicates a real difference. The value of q^* will increase if decision-makers getting optimistic regarding the demand forecast. This condition is in accordance with the equation 7, where q^* is directly proportional to the magnitude of the difference Δ_1 and Δ_2. The greater the difference of Δ, the greater the value of q^*.

Analysis of inventory in supply chain management of crude palm oil is an effort to integrate the economies scale and the fulfillment of sales plans. Auction system in crude palm oil sales by joint marketing office will be effective if supported by supply economic quantity information. This inventory information is also very useful in scheduling transportation from factory plant to port.

Optimal q^* value that exceeds or less than sales forecast (d) can be interpreted as economical amounts to be auctioned by the marketing unit. EOQ concept that is applied in the inventory control of crude palm oil is reflecting the economic quantity for sales. If the forecast value becomes the sales quantity reference, then the potential for high stock in the end of the month will occur. This condition is seen clearly in the case where q^* is greater than d. In the real condition, stock at the end of the year will be in a big amount. Integration between sales plan and the quantity of supply will enhance the effectiveness of inventory management.

Product availability in the factory bulk tank will determine the fulfillment ability of the port demand. The decision of the decision makers when selecting port demand fulfillment with the economic constraints needs to be analyzed furthermore by the supply chain optimization. More comprehensive analysis is needed so that economic scale can be achieved without sacrificing the factory utilization. This approach makes the completion of the real situation like this more easier.

Inventory control in the bulk tank is part of the quality risk management to achieve a superior value. This is based on the period of product stockpiling in port bulk tank that has to be maintained so it should not to be too long to reduce the risk of quality degradation. The quantity of the supply as the basis for sales planning needs to be *trade-off* with the sales forecasts to ensure the period of stockpiling in the bulk tank does not exceed the one month period. In heuristic, the *trade-off* can be determined by the following rules:

$$q^{adj} = Min\ \{q^*, d\} \qquad (11)$$

This policy is based on the efforts to maintain minimum inventory at the end of the period. This is not separated from the efforts of quality degradation risk management in the port bulk tank to keep the period of stockpiling does not exceed the one month period. If the best supply quantity (q^{adj}) is applied, then the cycle time (t_q) will be obtained as follows:

Table 2. Inventory policy q^{adj}

q^{adj}(ton)	t_q(month)
3,271	1
3,359	1
3,002	1
3,182	1
3,108	1
3,072	1
2,550	1
2,517	1
2,509	1
2,926	1
2,428	1
3,094	1

Discussion

In the supply chain system of crude palm oil, inventory of crude palm oil as the product emerges as the economic motive and the consequences of push product system. Fluctuations of product demand from the industrial consumers and fluctuations of the fresh fruit bunches supply from various sources are synchronized through the bulk tank management. The main supply source of fresh fruit bunches to the factory are nucleus estate, plasma estate as well as third parties.

Inventory control at the factory level reflects the quantity of the economic production of crude palm oil, while inventory control in the port bulk tank reflects the number of economic supply to the port. The used inventory model is the EOQ which is combined with *fuzzy* logic to accommodate fluctuations in demand. Modification of EOQ model would give different results than the *con.* The difference of optimal value is determined by the fluctuations in demand or delivery of crude palm oil to the port. Optimal value of EOQ-*fuzzy* tends to be smaller than the EOQ-*crisp*. This phenomenon is caused by the attempt to anticipate the fluctuations in demand. Total inventory cost of EOQ-*fuzzy* is smaller than the EOQ-*crisp*. Comparison of inventory models at the port level can be explained as follows:

$$Q^{fuzzy} = Q^{crisp}\sqrt{1+\frac{(\Delta_2-\Delta_1)}{4d}} \qquad (12)$$

Fluctuations in demand with bias value of Δ has been anticipated in the model, so it produces smaller EOQ if not to consider the fluctuations in demand. Total inventory cost EOQ-*fuzzy* is smaller than the EOQ-*crisp*. The model that was developed in *conventional* EOQ model.

This study was able to control the inventory with demand in the certain value interval. Low, medium and high demand conditions can be aggregated into an economic supply value with a minimum total inventory cost. The existence of this model is very useful for decision makers in analyzing the economic inventory level at the port in various scenarios.

The inventory control of crude palm oil is related to the quality risk because the greater volume of stored products and the longer period in stockpiling will trigger the oil quality change reactions such as contamination, enzymes actions, microbial actions and other chemical reactions. Stockpiling function should be begun as a synchronization effort of delivery schedule and is not only stockpiling. Inventory optimization is a supply chain management efforts that consider the risk of quality degradation. The result of inventory optimization will be the input in the optimization of the entire supply chain system.

CONCLUSION

This study has resulted mathematic model for inventory control of crude palm oil and a decision support system to assist decision maker in analyzing inventory policy in port bulk tank. The model of *fuzzy* EOQ that has been developed in this study is intended to accommodate the *fuzzy* demand. Result of the study shows that the optimal quantity of *fuzzy* EOQ is influenced by the value of Δ_1 and Δ_2. From the analysis of the three scenarios, it is known that the value of q^* will be increase if the decision-makers getting more optimistic regarding the upper limit of the sales forecast implementation.

Decision support system which is resulted can help the decision-makers in the operational planning and control of the supply to the port. Model is accommodating decision maker preference to anticipate demand in fuzzy environment.

The direction of further model development is to consider the risks of demand and stockpiling period in the bulk tank against the total inventory cost. Fuzzy conditions can be included in the model both on demand and product storage costs. Further model development can be carried out by developing a decision support system which is more comprehensive than the supply chain management of crude palm oil.

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