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Determining Order Size on Joint Inventory of Single Buyer and Seller With Fuzzy Demand

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ABSTRACT

Every company generally has problems about the company's inventory control system. The ability to meet demand with the right amount, time and location. Common models such as EOQ / EPQ are often used in inventory planning and control. The assumption of using this model requires cost and demand data that must be known and fixed. So that in solving inventory system problems sometimes there is a lack of information about similar data. So the development is needed to adjust to the conditions and industrial environment. One is an integration model between suppliers and buyers that results in lot sizes that minimize total inventory costs. Then it can be done an integration between suppliers and buyers by using fuzzy. This Model is designed to overcome the uncertainty of demand by describing it in the form of triangular fuzzy numbers. The results of the research using this method and involving an iterative approach obtained optimal results where the production quantity was 57,07 units and the delivery frequency was 3 times so that it could minimize the total inventory cost with a total cost of $242,05.

INTRODUCTION

Production planning is a very important thing in a production process, one of the processes is determining the company's lot size (Rahmanto & Dahda, 2022). Today, many industries are trying to increase competitive advantages by reducing costs, improving product quality, service and demand fulfillment capabilities (Dahda & Andesta, 2022). By harmonizing the amount of production, the amount of stored products, and the costs incurred from production and stored products allows the company to increase its competitive advantage.

One of the most common methods for managing raw material inventory control is the Economic Order Quantity (EOQ) method (Mayasari, 2021). The EOQ serves to determine the most economical purchase amount, which means that the company will bear minimal costs (Baharuddin et al., 2024). A further development was made by Taft (1918) by making the level of inventory fulfillment Limited, which is referred to as the limited level of production. And the model is known as Economic Production Quantity (Dahda & Andesta, 2022).

The use of EOQ/EPQ models is a concern and is being developed with many models adapted to the industrial situation applying those models (Tarhini, 2020). At first, the eoq and EPQ models were often used separately, but today they are widely used as combined models in research. The purpose of this combined model, known as the vendor-buyer integration model is to find the ideal order size under integration conditions.

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In general, the level of demand is always assumed to be continuous and constant (Romadlon & Dahda, 2022). Looking at the current conditions of demand is difficult in the real world. or orders vary greatly over time depending on the situation. Sometimes, demand can also peak during uncertain times in some markets (Malik & Garg, 2021). One of the settlement models of EOQ/EPQ models with non-constant demand is to use demand assumptions described in the form of fuzzy numbers. Fuzzy model approach as a determinant of optimal size, thus, fuzzy theory is feasible to be used to overcome inventory problems with these constraints (A. S. Nasution et al., 2023).

Fuzzy logic is one of the methods that is often used to overcome problems that contain uncertainty (Fadila, 2022). Fuzzy logic is considered capable of producing an output based on a certain parameter r without ignoring the existing factors (V. M. Nasution & Prakasa, 2019). Fuzzy logic is said to be very flexible and adaptable to the facts found (Dwi Antoni & Findawati, 2024). The purpose of the model in this study is to balance the cost of storage and inventory management by determining the optimal lot size using a fuzzy model.

RESEARCH METHODS

EOQ and EPQ

In this study used two inventory models with EPQ as vendor and EOQ as buyer. At this stage must pay attention to the cost component that is used as a determining parameter for decision variables. At the buyer related costs are the cost of saving and baiya message. While vendors have storage costs, set-up costs and shipping costs for each lot of production to the buyer (Rahmanto & Dahda, 2022). So fuzzy model is used in this study.

System Overview

Depiction of the first single vendor-single buyer inventory system is like the buyer inventory model depicted in Figure 1, and the vendor inventory model is depicted as in Figure 2. At the beginning of the cycle, the vendor will send the finished product as many times as the needs of one cycle buyer (q). The delivery time is right after the number of buyer needs is met (q/P). At the next stage, the vendor will send a q number of products according to the buyer's usage cycle or right at the time the buyer's inventory runs out (q/D). In the first model has the advantage that the buyer can immediately receive his order without waiting for the vendor to reach a certain amount.

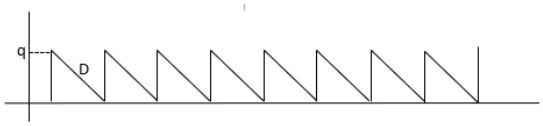


Figure 1 Buyer Inventory Model

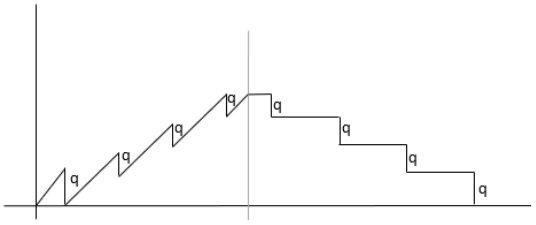


Figure 2 Vendor Inventory Model

The cost of inventory at one vendor and one buyer with buyer inventory model as shown in Figure 1 and vendor inventory model as shown in Figure 2. In buyer, inventory cost is calculated by store cost and message cost. The cost equation in the EOQ model applies to this calculation. By using the JIT concept, where buyers and vendors have a long-term cooperative relationship so

that the cost of buyer messages is only done once every vendor production cycle (Dahda & Andesta, 2022).

$$TCb = Chb.\frac{q}{2} + Crb.\frac{D}{Q}$$
$$TCb\ (Q,n) = Chb.\frac{Q}{2.n} + Crb.\frac{D}{Q} \quad (1)$$

At vendors, the inventory costs that will be taken into account are storage costs and set-up costs (Galih, Kurniawan, and Furwanto 2022). In addition to these two costs vendors also bear the cost of shipping shipping costs. The determination of storage costs is largely determined by the average inventory, obtained from the quotient of time-weighted inventory by time per cycle (Dahda and Andesta 2022).

As for the cost of inventory $T\ C\ v\ (Q,n)$ with the first vendor inventory model consisting of three cost components, message cost, shipping cost and store cost (Dahda and Andesta 2022).

$$TCv\ (Q,n) = Crv.\frac{D}{Q} + Chv.\frac{Q}{2.n}\left[(n-1) + (2-n)\left(\frac{D}{P}\right)\right] + Cdv.\frac{n.D}{Q} \quad (2)$$

The total cost $T\ C$ total (Q,n) which is the total combined cost of vendors and buyers from the sum of equations (1) and (2).

$$TC = Chb.\frac{Q}{2.n} + Chv.\frac{Q}{2.n}(n-1) + Chv.\frac{Q.D}{2.n.P}(2-n) + Crb.\frac{D}{Q} + Crv.\frac{D}{Q} + Cdv.\frac{n.D}{Q} \quad (3)$$

The production quantity (Q) is a continuous variable while the decision variable n is a discrete variable (Rahmanto & Dahda, 2022). With $TCtotal\ (Q,n)$ as a function of the convex equation and by determining the value of a certain n the value of the quantity of production that can minimize the total cost $TCtotal\ (Q,n)$, obtained from the first derivative$TCtotal\ (Q,n)$ against Q who meet $\frac{\partial TCtotal}{\partial Q} = 0$.

$$\frac{\partial TCtotal}{\partial Q} = -(Crv + Crb + Cdv.n).\frac{D}{Q^2} + \left(Chb + Chv\left[(n-1) + (2-n)\left(\frac{D}{P}\right)\right]\right)/2.n \quad (4)$$

Value $Q*(n)$ as the value of the decision variable quantity of production at a certain value N that minimizes the value $TCtotal\ (Q,n)$ is.

$$Q^*(n) = \frac{2.D.n.(Crb + Crv + Cdv.n)}{Chb + Chv.(n-1) + \frac{Chv.D.(2-n)}{P}} \quad (5)$$

Convexity test using the 2nd derivative of the equation $TCtotal\ (Q,n)$, konvks condition is reached if $\partial^2 TCtotal/\partial^2 TCtotal\ > 0$ and obtained.

$$\frac{\partial^2 TCtotal}{\partial Q^2} = (\text{Crv} + \text{Crb} + \text{Cdv.n}).\frac{D}{Q^3} > 0 \quad (6)$$

$TCtotal\ (Q,n)$ have a minimum value of $Q*(n)$.

Table 1 Decscription of symbol

Symbol	Decscription
D	Demand rate (units / units of time)
P	Production rate (units / units of time)
Chb	Buyer's saving cost ($/unit / time unit)
Crb	Buyer message cost ($/message)
Chv	Vendor save cost ($/unit / time unit)
Crv	Vendor message cost ($/message)
Cdv	Shipping cost ($/ message)
n	Frequency of delivery to the buyer in one production cycle of the vendor
q	Quantity of each shipment (units)
$T1$	Production time (unit of time)
T	Cycle time (unit of time) where T=T1+T2
Q	Quantity of production (units), where Q=q.n

Fuzzy

Fuzzy logic allows membership values to lie between 0 and 1. This implies that two values " yes and no", "right and wrong", "good and bad" can appear in the scenario at the same time, but the amount of value depends on the weight of the membership it has (Dwi Antoni & Findawati, 2024).

Fuzzy set is a set in which there are elements that have different degrees of membership (Yulianto et al., 2012). A fuzzy set is defined as a membership function of μ ((r̃) (r) which maps each and every element of to the range from 0 to 1, or can be written as μ (r̃) (r) → [0, 1] Where is the universal set. Defined simply, fuzzy sets are sets that do not have strict limits (Maity et al., 2019). On the other hand, a fuzzy set is a set that has elements with characteristics such as the membership function above (Davvaz et al., 2021).

A Fuzzy number r̃ is a fuzzy set defined in that it has a membership level of μ(r̃), which is assumed (Romadlon & Dahda, 2022).

1. Convex
2. Normalized fuzzy set
3. Piecewise Continuous

Suppose that r̃ is a fuzzy number, the α-cut of r̃ denoted by r̃_α̃ is the set of real numbers for which the membership function of r is not smaller than α. It can be written in the form r _α = {r | μ (r) (r) ≥ α,r R} (Dahdah, 2018). The Support of a fuzzy set is a crisp (firm) number subset of the basic set (Romadlon & Dahda, 2022). Can be written in Supp form $(r) = \{r \mid \mu\,(r)\,(r) \geq 0, r\ R\}$.

The membership function is a curve that shows the mapping of the value of input data (domain) to its membership value by agreeing with a form of function (Davvaz et al., 2021). One of the membership functions (curves) is triangular/triangular (triangular fuzzy number). The Shape of this curve is as shown in the figure, where r is denoted by (a,b, c) where a ≤ b ≤ c and the membership function are defined as follows (Singh, 2021):

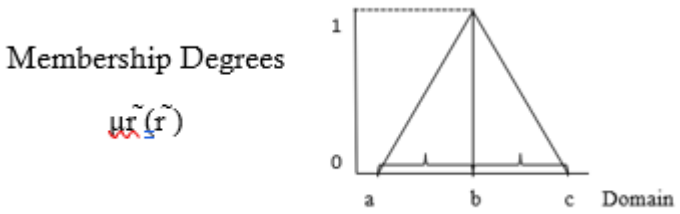


Figure 3 Membership Degree Triangle

$$M(\tilde{r}) = \begin{cases} 0 & x \leq a x \geq c \\ \dfrac{a - x}{b - a} & a \leq x \leq b \\ \dfrac{b - x}{c - b} & b \leq x \leq c \end{cases} \quad (7)$$

Description :

a = lowest demand value

b = Middle value of raw material inventory

c = highest demand value

Where, a,b, c R by using the concept of definition 3, when given the confidence coefficients of the Triangle fuzzy numbers will be defined as a set with closed intervals. The Interval r _α = (r (α− L) ; r _(α−U)) = {a+α(b−a);c−α(c− b)}∀$a\epsilon$ [0,1] (Dahdah, 2018).

The process of affirmation (de-fuzzification) is the output process of a fuzzy rules is the domain of fuzzy sets that must be converted into a firm number (crisp) (Dahdah, 2018). There are several methods used for the defuzzification process one of which is used in this method is the center of gravity or centroid method which is the most famous and efficient method (Jalali Khalil Abadi & Mansouri, 2024). In this method, the crisp number is taken by taking the center point of fuzzy area (Handayani et al., 2019). To obtain it, the fuzzy set will be transformed into a firm number by the formula.

Where $\tilde{D}$ is a fuzzy number the demand assumed membership function represents a symmetric triangular curve, where Δdi and Δdh is equal (Dahdah, 2018). A fuzzy number $\tilde{D}$ is defined with support $[Di;Du]$ where D_m is the maximum degree of membership. where D_m is the lower limit of the request, where $D\ \tilde{D}= [Di;Dm;Du]$ and $Di;Dm;Du \in R$ and Di, where D_m is the lower limit of the request, is the middle value of the request and D_u is the limit of the request. The degree of membership of D_l and D_u is 0 and the degree of membership of D_m reaches the number 1 (Romadlon & Dahda, 2022).

Steps Of Fuzzy Logic Research Method

The fuzzy logic research method is an approach that uses fuzzy logic to analyze and model unclear or ambiguous systems (Muhammad Afdhal et al., 2021). Fuzzy logic is an extension of traditional logic that allows the spread of truth values between true and false (Alateeq & Pedrycz, 2024). In fuzzy logic, variables can have different levels of membership in a set. Here are the general steps in the fuzzy logic research method:

Step 1 identification of variables: identification of the variables involved in the system to be studied. Variables can be inputs, outputs, or intermediate variables.

Step 2 Define a Fuzzy set: define a fuzzy set for each variable that has been identified. Fuzzy sets consist of membership sets that model the degree of correctness of variables in a domain.

Step 3 Define a membership function: define a membership function for any predefined fuzzy set. The membership function describes the relationship between an input variable and its level of membership in the set.

Step 4 Defuzzification: defuzzification method functions to convert fuzzy output into concrete values. Defuzzification combines the results of fuzzy inference into a single value that can be used in analysis or decision making.

Step 5 validation and Evaluation: validate and evaluate fuzzy models to ensure compatibility with data and research objectives. This involves testing the model using eoq and EPQ integration formulas

Steps Of EOQ And EPQ Integration Methods

Step 1 Determine the degree of fuzzy membership

Step 2 determine n = 1

Step 3 Determine Q (n) with the result of Step 1

Step 4 Define $T\ C\ (Q,n)$

Step 5 determine $n = n + 1$ and repeat steps 3 and 4

Step 6 if $TC\ (Q,n) \leq TC\ (Q,n\text{-}1)$ Go To Step 5, otherwise go to step 7

Step 7 Specify $Q*$ and $n*$ equal to the value of $(Q,n-1)$, where $Q*$ and $n*$ is the solution in the determination of the size of production and the number of deliveries per cycle is optimal.

RESULTS AND DISCUSSION

Inventory refers to all types of economically valuable resources that are in various stages of production and ready for sale. Inventory uncertainty is a common phenomenon whose occurrence reduces the profitability of the company by increasing the minimum operating costs. In most of the real-world inventory problems, we face a lot of uncertainty in the key parameters of the model concerned.

This imprecision and uncertainty in the EOQ/EPQ model are corrected by using fuzzy set theory. So, in this context, the inventory order level is developed by taking the holding cost and shortage cost as triangular fuzzy numbers.

Relevant numerical examples are illustrated along with sensitivity analysis to justify the proposed idea that the optimal value is improved in the fuzzy method as compared to using only the traditional EOQ/EPQ method. With reference data as an illustration of the solution development. The following demand data is an estimate in the form of a linguistic utterance, the demand (D) of the canon product is 500 units/year, but will not be less than 100 units/year and will not be more than 800 units/year. P = 1,400 units/year, Chb= \$6/unit/year, Crb = \$30/order, Chv = \$3/unit/year, Crv= \$50/set-up, Cdv= \$15/shipment.

In previous studies, the discussion of single buyers and single vendors calculated traditional EOQ/EPQ where product demand was not defuzzified so that the demand in this calculation was 500 units/year. Calculations were made using a formula without looking for the degree of membership.

$$Q^{2*}(n) = \frac{2.500.n.(30 + 50 + 15.n)}{6 + 3.(n-1) + \frac{6.500.(2-n)}{1.400}}$$

The results obtained from the EOQ/EPQ calculation using the following formula:

Table 2 Traditional analysis results

n	Q	TC*total*
1	37,13	269,25
2	51,63	232,37
3	62,50	223,97
4	71,55	223,60
5	79,47	226,49
6	86,60	230,94
7	93,14	236,18
8	99,22	241,86

Calculation of EOQ/EPQ using the fuzzy method is done by determining the degree of membership with the following formula:

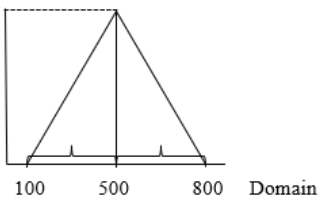
$$M(\tilde{r}) = \begin{cases} 0 & x \leq a x \geq c \\ \frac{a-x}{b-a} & a \leq x \leq b \\ \frac{b-x}{c-b} & b \leq x \leq c \end{cases} \quad (8)$$

$$\tilde{r}\propto = \{a + \propto (b - a) ; c - \propto (c - a)\} \quad (9)$$

Demand is described as a fuzzy number in the form of a triangle so that it can be described as follows:

Membership Degrees

$\mu\tilde{r}(\tilde{r})$



$$M(\tilde{r}) = \begin{cases} 0 & x \leq 100 \geq 800 \\ \dfrac{a-x}{b-a} & 100 \leq x \leq 500 \\ \dfrac{b-x}{c-b} & 500 \leq x \leq 800 \end{cases}$$

$$\tilde{r}\propto = \{100 + 400 \propto ; 800 - 300 \propto\}$$

With the known degree of membership calculation is done to find the value of the decision variable quantity of production ($Q^*(n)$).

$$Q^* = \begin{cases} 0 & x \leq 714{,}89 \geq 6720 \\ \dfrac{100 - 400\propto}{500 - 100} & 714{,}89 \leq x \leq 3906{,}97 \\ \dfrac{800 - 300\propto}{800 - 500} & 3906{,}97 \leq x \leq 6720 \end{cases}$$

Table 3 Fuzzy analysis results

n	Q	TC*total*
1	33,24	273,53
2	46,68	244,98
3	57,07	242,05
4	65,91	245,96
5	73,77	252,46
6	80,92	260,08
7	87,53	268,19
8	93,71	276,49

In table 2 with the traditional EOQ/EPQ model, the optimal size (Q^*) in the combined EOQ and EPQ models is shown with the result (Q^*) = 71.55 units with an optimal delivery frequency (n) of 4 times and a total cost of $223.60. In table 3 with the EOQ/EPQ model using fuzzy, the optimal size (Q^*) is shown with the result (Q^*) = 57.07 units with an optimal delivery frequency (n) of 4 times and a total cost of $242.05. Tables 2 and 3 show each different value of n that affects T$Ctotal$ (Q,n) for the inventory model for vendors and single buyers.

CONCLUSION

This study discusses the integration of EOQ models for buyers and EPQ for suppliers using a fuzzy triangle approach to overcome uncertainty. Fuzzy logic is used to model uncertain demand, allowing flexibility in analysis. Determination of the optimal lot size is done by modeling demand as a triangular fuzzy number. The EOQ-EPQ integration method uses iterative steps to

determine the optimal value of production quantity (Q*) and delivery frequency (n) based on minimum total cost.

Simulation results with numerical examples show that with the fuzzy approach the average inventory is 57.07 units, in the traditional model the average inventory is 71.55 units. The traditional EOQ/EPQ model produces a larger lot size, but the total inventory cost is lower than the fuzzy model. The fuzzy model shows better flexibility in dealing with demand uncertainty, although the total cost is slightly higher. By using fuzzy, the average inventory size becomes smaller than the traditional method, allowing for the reduction of excess stock. This study shows that the fuzzy approach can be effectively integrated with the EOQ and EPQ models to create a more adaptive and efficient inventory system. This research enables companies to manage demand uncertainty and reduce operational costs. The flexibility of fuzzy logic in handling uncertain or incomplete data and the ability to adapt to dynamic and varied industry needs.

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