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OPTIMIZATION OF RICE INVENTORY USING FUZZY INVENTORY MODEL AND LAGRANGE INTERPOLATION METHOD

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ABSTRACT

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Interpolation is a method to determine the value that is between two values and is known from the data. In some cases, the data obtained is incomplete due to limitations in data collection. Interpolation techniques can be used to obtain approximate data. In this study, the Lagrange interpolation method of degree 2 and degree 3 is used to interpolate the data on rice demand. A trapezoidal fuzzy number expresses the demand data obtained from the interpolation. The other parameters are obtained from company data related to rice supplies and are expressed as trapezoidal fuzzy numbers. The interpolation accuracy rate is calculated using Mean Absolute Percentage Error (MAPE). The second-degree interpolation method produces a MAPE value of 30.76 percent, while the third-degree interpolation has a MAPE of 32.92 percent. The quantity of order Q_4, Q_3, Q_2, Q_1, respectively 202677 kg, 384610 kg, 1012357 kg, 1447963 kg, and a total inventory cost of Rp. 129231797951.

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1. INTRODUCTION

The concept of inventory can be applied to the problem of optimizing inventory, inventory levels, optimal order time, and the optimal amount of inventory for reordering to minimize the total costs incurred due to inventory. Research related to inventory and methods has been developed and applied in various fields. Inventory problems with various payment systems are discussed by [1]. The algebraic method is used by [2] to solve the inventory model. The modified fruit fly algorithm method was introduced by [3] to solve the optimization problem of allocation and inventory. In [4], the problem of inventory for perishable products. The application of the concept of inventory in the health sector is discussed in [5]. Optimization of the red chili inventory system using the fuzzy inventory probabilistic model is discussed by [6].

The EOQ inventory model can be used in optimization problems that aim to obtain the optimal amount of inventory and reorder time by considering demand parameters. The following is a research on inventory problems using the EOQ model. Inventory problems using the EOQ model with nonlinear constraints are given by [7]. Research related to inventory problems using the EOQ model by considering the level of damage and inventory depending on demand is discussed [8]. The application of the EOQ model with demand assumed to be a nonlinear function is discussed by [9].

In some cases, the inventory model parameters are uncertain. For example, the demand parameter for an item for each period is not always the same and fluctuates. So, to determine the value of these parameters, the interpolation technique can be done. Interpolation is a method to get a value that is between range values. Several interpolation techniques have been developed. The following is research related to the application of the interpolation method. The study of Spline interpolation is given by [10]. [11] used Kriging interpolation on a nonlinear model to predict rock shear strength. The use of the Cubic-B-Spline interpolation method on the boundary value problem was introduced by [12]. The multi-level quadratic spline interpolation technique was introduced by [13]. Newton's polynomial interpolation was used by [14] on underwater ROV systems. [15] introduced Newton's multi-variable polynomial interpolation method. In addition to the interpolation methods already mentioned, fractal interpolation methods have been developed and applied in various fields. The use of fractal interpolation in time series data was introduced by [16]. Fractal interpolation on Covid-19 data is discussed by [17]. Fractal interpolation is also applied by [18] to seismic data by introducing a scale factor.

The interpolated data is the result of the approach, not the actual data. Therefore, the deterministic approach is inappropriate. Fuzzy, probabilistic, and stochastic approaches can be used for uncertain parameters. The EOQ model with fuzzy parameters is called the fuzzy EOQ model (FOQ). The following is research related to the application of the fuzzy EOQ model. The fuzzy EOQ model was developed by [19] with the request parameter expressed as cloudy fuzzy. Fuzzy numbers express the fuzzy EOQ inventory model with demand parameters, and the defuzzification technique using Graded Mean Integration is discussed by [20]. The fuzzy EOQ model, considering the discount proportion factor, is discussed by [21]. The procedure for solving the fuzzy EOQ model is given by [22] and [23]. This study will apply the Lagrange interpolation technique to the rice demand data. The interpolation technique is carried out to determine the value of the rice demand parameter approach based on price. Rice is one of the primary needs of Indonesian people. The demand for rice in each ordering period is different. Therefore, a technical approach is needed to determine the number of rice orders from suppliers to fulfill customer demand. The demand for interpolation results is approximate so that the fuzzy approach can be applied. Generally, the maximum and minimum limits for rice demand can be determined. Demand is constant at certain price intervals, and at certain prices, it increases or decreases. Trapezoidal fuzzy numbers can be used to express rice demand parameters. Data interpolated are expressed as trapezoidal fuzzy numbers and as fuzzy parameters in the fuzzy EOQ model introduced by [22] and [23]. This study developed a fuzzy EOQ model by considering the level of demand, holding costs, and inventory procurement capabilities.

2. RESEARCH METHODS

This study applies the Lagrange interpolation method to determine demand data in the inventory model. Interpolation of demand data is determined based on the selling price. A Trapezoidal fuzzy number expresses the interpolated demand data. The FEOQ model is used to determine the optimal inventory. The stages of solving inventory optimization problems are given as follows.

2.1 Lagrange Interpolation Method

The Lagrange polynomial interpolation function is given by [24]. In the j-th dimensional search space, the Lagrange interpolation polynomial $P(x_j)$ of degree d pass through $d+1$ different given points $\left(x_j^0, f(x^0)\right), \left(x_j^1, f(x^1)\right), \cdots, \left(x_j^d, f(x^d)\right), j = 1, \cdots, D$, where x_j^k is the j-th parameter in the vector $x^k = \{x_1^k, x_2^k, \cdots, x_D^k\}, k = 0, \cdots, d$, $f(x^k)$ is the corresponding fitness value of x^k and $f(x^k) = f([x_1^k, x_2^k, \cdots, x_D^k])$. It Satisfies $P(x_j^k) = f(x^k)$, as shown in Equation (1).

$$P(x_j) = \sum_{k=0}^{d}\left[\left(\prod_{\substack{m=0\\ m\neq k}}^{d} \frac{x_j - x_j^m}{x_j^k - x_j^m}\right) f(x^k)\right], j = 1, \cdots, D \tag{1}$$

$P(x_j)$ is the polynomial of fitness $f(x)$. Equation (1) for an interpolation of degree 2 can be rewritten as follows.

$$P(x_2) = \frac{(x-x_1)(x-x_2)}{(x_0-x_1)(x_0-x_2)} f(x_0) + \frac{(x-x_0)(x-x_2)}{(x_1-x_0)(x_1-x_2)} f(x_1) + \frac{(x-x_0)(x-x_1)}{(x_2-x_0)(x_2-x_1)} f(x_2) \tag{2}$$

Equation (1) for an interpolation of degree 3 can be rewritten as follows.

$$P(x_3) = \frac{(x-x_1)(x-x_2)(x-x_3)}{(x_0-x_1)(x_0-x_2)(x_0-x_3)} f(x_0) + \frac{(x-x_0)(x-x_2)(x-x_3)}{(x_1-x_0)(x_1-x_2)(x_1-x_3)} f(x_1) + \frac{(x-x_0)(x-x_1)(x-x_3)}{(x_2-x_0)(x_2-x_1)(x_2-x_3)} f(x_2) + \frac{(x-x_0)(x-x_1)(x-x_2)}{(x_3-x_0)(x_3-x_1)(x_3-x_2)} f(x_3) \tag{3}$$

2.2 Trapezoidal Fuzzy Number and Mean Integration Method

Trapezoidal fuzzy number (n_1, n_2, n_3, n_4) is given in Figure 1.

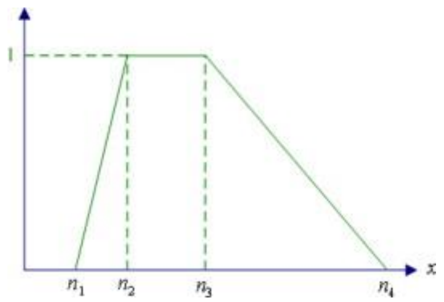

Figure 1. Trapezoidal fuzzy number

The mean integration method is used for the defuzzification stage [23].

Let $\widetilde{B} = (n_1, n_2, n_3, n_4)$, $P(\widetilde{B}) = \frac{n_1 + 2n_2 + 2n_3 + n_4}{6}$

2.3 Fuzzy Economic Order Quantity (FOQ) Model

Given the total cost, one cycle is as follows.

$$TC(Q, P) = \frac{K(a-bP)}{Q} + c(a-bP) + \frac{gcP}{2} \tag{4}$$

A partial differential of Equation (4) with respect to Q and the result equal to zero is obtained.

$$Q = \sqrt{\frac{2K(a-bP)}{gc}} \tag{5}$$

By using Trapezoidal fuzzy numbers $Q_i, K_i, P_i, c_i, a_i b_i$, and g_i, the following is given a FEOQ model introduced by [23].

$$JTC(Q) = 1/6\left[\left(\frac{K_1(a_1-b_1P_1)}{Q_4} + c_1(a_1-b_1P_1) + \frac{g_1c_1Q_1}{2}\right) + 2\left(\frac{K_2(a_2-b_2P_2)}{Q_3} + c_2(a_2 - b_2P_2) + \frac{g_2c_2Q_2}{2}\right) + 2\left(\frac{K_3(a_3-b_3P_3)}{Q_2} + c_3(a_3-b_3P_3) + \frac{g_3c_3Q_3}{2}\right) + \left(\frac{K_4(a_4-b_4P_4)}{Q_1} + c_4(a_4-b_4P_4) + \frac{g_4c_4Q_4}{2}\right)\right] \tag{6}$$

A partial differential of **Equation (6)** with respect to $\boldsymbol{Q_i}, i = 1,2,3,4$, and the result equal to zero is obtained.

$$Q_1 = \sqrt{\frac{2K_4(a_4 - b_4P_4)}{g_1c_1}} \quad (7)$$

$$Q_2 = \sqrt{\frac{2K_3(a_3 - b_3P_3)}{g_2c_2}} \quad (8)$$

$$Q_3 = \sqrt{\frac{2K_2(a_2 - b_2P_2)}{g_3c_3}} \quad (9)$$

$$Q_4 = \sqrt{\frac{2K_1(a_1 - b_1P_1)}{g_4c_4}} \quad (10)$$

where:

K_i : ordering cost

a_i : constant demand rate coefficient

b_i : price-dependent demand rate coefficient

P_i : selling price

Q_i : ordering size

c_i : unit purchasing cost

g_i : constant holding cost coefficient

i = 1,2,3,4

3. RESULTS AND DISCUSSION

In this research, interpolation was carried out using Lagrange interpolation techniques to determine rice demand based on price. Initial conditions are selected based on prices at the highest and lowest price intervals. The highest and lowest prices are 12000 and 10000 respectively. Using **Equation (2)** and **Equation (3)**, we obtain 2nd and 3rd-order Lagrange interpolation functions with initial conditions (10000, 10800, 12000) and (10000, 10800, 11400, 12000).

$$P_2(x) = \left(\frac{(x-12000)(x-10000)}{(10800-12000)(10800-10000)}\right)(1177733) + \left(\frac{(x-10800)(x-10000)}{(12000-10800)(12000-10000)}\right)(362400) + \left(\frac{(x-10800)(x-12000)}{(10000-10000)(10000-12000)}\right)(3138678.5)$$

$$P_3(x) = \left(\frac{(x-11400)(x-12000)(x-10000)}{(10800-11400)(10800-12000)(10800-10000)}\right)(1177733) + \left(\frac{(x-10800)(x-12000)(x-10000)}{(11400-10800)(11400-12000)(11400-10000)}\right)(2419069) + \left(\frac{(x-10800)(x-11400)(x-10000)}{(12000-10800)(12000-11400)(12000-10000)}\right)(362400) + \left(\frac{(x-10800)(x-11400)(x-12000)}{(10000-10800)(10000-114000)(10000-12000)}\right)(3138678.5)$$

The following are the 2nd-degree and 3rd-degree Lagrange interpolation results. Variable x can be replaced with the price of rice, which will determine the value of the demand approach. Interpolation calculations using Python programming.

Table 1. Lagrange Interpolation 2nd Degree and 3rd degree

Time	Price (Rupiah)	Demand (Kg)	2nd Interpolation	3rd Interpolation
January	10500	1877819	1780207.23	901673.62
February	10150	1512299	2684629.01	1980337.89
March	10800	1177733	1177733.00	1177733.00
April	11550	1405435	369169.14	2411759.78
May	11400	2419069	451153.71	2419069.00
June	12000	362400	362400.00	362400.00
July	10250	1966169	2404076.06	1464533.17
August	10500	1848084	1780207.23	901673.62
September	10400	1449570	2016466.73	1016890.71
October	11800	923049	321115.06	1726768.83
November	10350	2119598	2141240.50	1126534.17
December	10000	3138678.5	3138678.50	3138678.50

The level of accuracy is calculated using the Mean Absolute Percentage Error (MAPE). MAPE interpolation 2nd Degree is 30.76 percent, and degree 3 is 32.92 percent. Rice inventory optimization calculation using 2nd degree interpolated demand data.

Table 2. Parameter Value

Parameter	Fuzzy Parameter
K_i	(250; 450; 650; 1050)
a_i	(321115; 600295; 2504218; 3138679)
b_i	(11.287; 12.108; 26.604; 50)
P_i	(1.181; 1.148; 1.245; 1.249)
c_i	(9200; 9400; 9600; 9800)
g_i	(28.92; 29.86; 35.06; 38.30)

The fuzzy parameter constant demand rate coefficient a_i is determined based on the results of 2nd-degree interpolated demand data by considering the lowest, highest, and average demand. Other parameters are determined based on actual data. Based on the fuzzy parameter values in Table 2 and Model (6) to (10) obtained

1. The quantity of order Q_4, Q_3, Q_2, Q_1, respectively 202677 kg, 384610 kg, 1012357 kg, 1447963 kg.
2. Total inventory cost of Rp 129231797951.

4. CONCLUSIONS

Based on the results of calculations using rice inventory data in one company, it can be concluded that

1. The interpolated MAPE value of degree 2 is smaller than degree 3.
2. Trapezoidal fuzzy parameters provide four optimal inventory solutions. The larger the trapezoidal fuzzy number, the smaller the optimal inventory amount.

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REFERENCES

[1] S. Sanni and B. O. Neill, "Computers & Industrial Engineering Inventory optimisation in a three-parameter Weibull model under a prepayment system," *Comput. Ind. Eng.*, vol. 128, no. December 2018, pp. 298–304, 2019.

[2] X. Luo and C. Chou, "International Journal of Production Economics Technical note : Solving inventory models by algebraic method," *Int. J. Prod. Econ.*, vol. 200, no. March, pp. 130–133, 2018.

[3] S. M. Mousavi and D. Ph, "Optimizing a location allocation-inventory problem in a two-echelon supply chain network : A modified Fruit Fly optimization algorithm," *Comput. Ind. Eng.*, 2015.

[4] J. Rezaeian, S. Haghayegh, and I. Mahdavi, "Designing an Integrated Production / Distribution and Inventory Planning Model of Fixed-life Perishable Products," *J. Otimization Ind. Eng.*, vol. 19, pp. 47–59, 2016.

[5] Y. Perlman and I. Levner, "Perishable Inventory Management in Healthcare," *J. Serv. Manag.*, vol. 2014, no. February, pp. 11–17, 2014.

[6] E. Susanti, R. Sitepu, K. Ondhiana, and W. D. Wulandari, "Optimization of Inventory Level Using Fuzzy Probabilistic Exponential Two Parameters Model," *J. Mat. MANTIK*, vol. 7, no. 2, pp. 124–131, 2021.

[7] L. E. Cárdenas-barrón, A. A. Shaikh, S. Tiwari, and G. Treviño-garza, "An EOQ inventory model with nonlinear stock dependent holding cost, nonlinear stock dependent demand and trade credit," *Comput. Ind. Eng.*, vol. 139, p. 105557, 2020.

[8] A. A. Shaikh, M. A. A. Khan, G. C. Panda, and I. Konstantaras, "Price discount facility in an EOQ model for deteriorating items with stock-dependent demand and partial backlogging," *Int. Trans. Oper. Res.*, vol. 26, no. 4, pp. 1365–1395, 2019.

[9] L. E. Cárdenas-Barrón, A. A. Shaikh, S. Tiwari, and G. Treviño-Garza, "An EOQ inventory model with nonlinear stock dependent holding cost, nonlinear stock dependent demand and trade credit," *Comput. Ind. Eng.*, vol. 139, no. December 2018, p. 105557, 2020, doi: 10.1016/j.cie.2018.12.004.

[10] F. Geng and X. Wu, "Reproducing Kernel Functions Based Univariate Spline Interpolation," *Appl. Math. Lett.*, vol. 122, p. 107525, 2021.

[11] M. Hasanipanah, D. Meng, B. Keshtegar, N. T. Trung, and D. K. Thai, "Nonlinear Models Based on Enhanced Kriging Interpolation for prediction of Rock Joint Shear Strength," *Neural Comput. Appl.*, vol. 33, no. 9, pp. 4205–4215, 2021.

[12] S. Tayebi, S. Momani, and O. Abu Arqub, "The Cubic B-Spline Interpolation Method for Numerical Point Solutions of Conformable Boundary Value Problems," *Alexandria Eng. J.*, vol. 61, no. 2, pp. 1519–1528, 2022.

[13] P. Lamberti and A. Saponaro, "Multilevel Quadratic Spline Quasi-Interpolation," *Appl. Math. Comput.*, vol. 373, 2020.

[14] G. I. Gandha and D. Nurcipto, "The Newton's Polynomials Interpolation Based-Error Correction Method for Low-Cost Dive Altitude Sensor in Remotely Operated Underwater Vehicle (ROV)," *J. Infotel*, vol. 11, no. 1, p. 1, 2019.

[15] L. Zou, L. Song, X. Wang, T. Weise, Y. Chen, and C. Zhang, "A New Approach to Newton-Type Polynomial Interpolation with Parameters," *Math. Probl. Eng.*, vol. 2020.

[16] S. Raubitzek and T. Neubauer, "A fractal interpolation approach to improve neural network predictions for difficult time series data," *Expert Syst. Appl.*, vol. 169, no. August 2020, p. 114474, 2021.

[17] C. M. Păcurar and B. R. Necula, "An Analysis of COVID-19 Spread based on Fractal Interpolation and Fractal Dimension," *Chaos, Solitons and Fractals*, vol. 139, p. 110073, 2020.

[18] H. Ochoa, O. Almanza, and L. Montes, "Fractal-interpolation of seismic traces using vertical scale factor with residual behavior," *J. Appl. Geophys.*, vol. 182, p. 104181, 2020.

[19] S. Maity, S. K. De, and S. P. Mondal, *A study of an EOQ model under lock fuzzy environment*, vol. 7, no. 1. Springer Singapore, 2019.

[20] T. Nadu and T. Nadu, "Fuzzy Inventory EOQ Optimization," *Int. J. Electr. Eng. Technol.*, vol. 11, no. 8, pp. 169–174, 2020.

[21] R. Patro, M. M. Nayak, and M. Acharya, "An EOQ Model for Fuzzy Defective Rate with Allowable Proportionate Discount," *Opsearch*, vol. 56, no. 1, pp. 191–215, 2019.

[22] S. K. De, "Solving an EOQ Model under Fuzzy Reasoning," *Appl. Soft Comput.*, vol. 99, p. 106892, 2021.

[23] K. Kalaiarasi, M. Sumathi, H. M. Henrietta, and A. S. Raj, "Determining the Efficiency of Fuzzy Logic EOQ Inventory Model with Varying Demand in Comparison with Lagrangian and Kuhn-Tucker Method Through Sensitivity Analysis," *J. Model Based Res.*, vol. 1, no. 3, pp. 1–12, 2020.

[24] Q. Huang, K. Zhang, J. Song, Y. Zhang, and J. Shi, "Adaptive Differential Evolution with a Lagrange Interpolation Argument Algorithm," *Inf. Sci. (Ny).*, vol. 472, pp. 180–202, 2019.