World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Implementation of fuzzy logic model for fish supplier selection

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World Journal of Advanced Research and Reviews, 2022, 15(03), 115–124

Publication history: Received on 03 August 2022; revised on 06 September 2022; accepted on 08 September 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.15.3.0901

Abstract

This study aims to select the best supplier in the Dizma Koi Blitar business by using two variables as indicators of supplier assessment, namely low prices and minimal number of defective products. The data used in this study is secondary data in the form of a history of koi fish purchases to suppliers during the period from January to December 2021.The data analysis method used in this study is fuzzy logic mamdani programming. The results of the study in the form of measuring instruments determining the quality of koi fish suppliers provide calculations of two different sets of prediction data; the first prediction uses two input factors, while the second prediction uses five input variables. Both projections are quite close to the results of the first fish purchase, and the prediction of fish purchases is targeted for each month in 2021. The trial of the program using a price input of IDR 415,000.00 with defective products in one bag of 10 heads turned out to provide the predicted result of the supplier's quality value of 2.5282. The result of the predicted value if converted, the supplier is included in the very good category because with prices that are included in the affordable class and defective products are included in the very low category intervals get an assessment of the quality of suppliers in the very good category. When viewed using MAPE and MSE, the MSA value obtained is 2.3129, this indicates that the error rate in forecasting is very small. The fact that the MAPE value for test data with 2 input factors is the minimum possible value suggests that subsequent predictions can be made more accurately using this model, specifically by using more than 2 input variables.

Keywords: Fuzzy Logic; Programming; Selection; Fish Supplier Assessment, MAPE and MSE

1. Introduction

According to the government, companies are organizations with profit-oriented characteristics, whether individuals or groups own them. A healthy organization or company can be measured from several aspects, such as the maximum achievement of targets or goals by utilizing the available resources in production, marketing, finance, and human resources. Companies supported by a sound system will be able to maintain their survival. Therefore, companies need to conduct an assessment and review in all aspects.

A supplier is an organization that provides resources needed by customers, both in the form of material and non-material. In a company, the need for raw materials to components supplied by suppliers is an essential factor in the production line. Therefore, the supplier selection process is one of the most crucial development decisions and even influences the company's existence.

The dominant consideration factor in supplier selection is increasing the efficiency of raw material procurement. Research conducted by reveals that the costs incurred for procuring goods supplied by the suppliers can reach 70% of total product sales [1]. Supplier selection can be categorized as a long process because it is evaluated on several criteria

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such as price, quality, delivery, and other assessments. The main objective of the supplier selection process is to consistently fulfil the procurement of raw materials and components for the company's needs and minimize risk.

Companies can increase competitiveness by selecting the right supplier. Many suppliers can provide the materials or components needed, but not all resources can provide the best output by the company's goals. Therefore, companies need to conduct supplier assessments carefully. Supplier assessment requires various criteria to describe the supplier's performance so that it can help decision-makers determine choices. A study to identify several criteria for selecting the best supplier by sending questionnaires to 273 agents and procurement managers in the USA and Canada [2, 3]. Based on the identification, 23 criteria must be considered in selecting suppliers, including quality, order fulfilment, company performance history, guarantees, prices, and others. However, each company has different priority criteria for purchasing materials and production components. Moreover, companies tend to have more than one supplier for their raw materials. For example, to anticipate uncertain raw material needs, this situation brings the company to the problem of selecting alternative suppliers.

Many approaches or methods can be used to deal with the above problems, one of which is selecting and optimizing when decision-makers are faced with many supplier choices. These methods have been successfully implemented in many problem sectors. Another research developed fuzzy logic and goal programming to determine the weight of supplier selection with more than one objective function [3, 4]. The Study applied the Mamdani FIS approach [4,5,6] to creating a supplier selection decision support system by combining data and models with five criteria: price, quality, customer care, quantity accuracy, and delivery accuracy. Researcher applyingthe fuzzy logic method [5] to determine the order of supplier selection criteria. A supplier selection decision support system application using a web-based fuzzy logic method with three selection criteria: price, quality, and location [5, 6, 7].

The case study in this study is Dizma Koi Blitar, one of the MSMEs with promising business development prospects with marketing coverage throughout Indonesia. Dogma Koi Blitar sells koi fish products with the availability of various types and fish motifs. To satisfy customers, Dizma Koi Blitar strives to provide the best products. Suppliers mainly supply the products sold at Dizma Koi because Dizma Koi belongs to the retail MSME group. Dizma Koi Blitar markets its products online through the social media platform Facebook with coverage of buyers throughout Indonesia. Dizma Koi has more than 15 suppliers to supply raw materials for koi fish. In addition, not all fish products obtained from every supplier can be sold because there will be defective products. Dizma Koi also sees different specifications from suppliers in terms of quality, quantity, and price. After the fish is received from the supplier, Dizma Koi sorts the products based on the defect factor. The defects referred to are physical defects such as (a) broken or damaged fins, (b) broken or damaged tail, and (c) scales containing lice. After the product passes the sorting stage, the next step is to offer the product online on Facebook social media platform. The fish are then put in quarantine for two days. Then, the fish is ready to be sent according to the destination address. Based on the stages of operational activities, Dizma Koi Blitar has problems in not reviewing and evaluating suppliers according to the desired criteria. The criteria for selecting the desired supplier are the minimum number of defective products and low prices. Therefore, it is essential for Dizma Koi Blitar to choose suppliers optimally.

Dizma Koi Blitar can minimize failures in obtaining greater profits by choosing the optimal supplier and including the expectation factor of the number of products that may be rejected due to defects in each supplier. The above phenomenon is the basis for considering research [4, 6, 7, 8] on selecting koi fish suppliers at Dizma Koi Blitar with the Mamdani fuzzy logic method. The method introduced by Ebrahim Mamdani in 1975 is often known as the max-min or max-product method. Mamdani fuzzy method is widely used for research on intelligent systems. The intelligent system can be in the form of an expert system or a Decision Support System (SPK). So this research has the title Selection of a Koi Fish Supplier Using a Fuzzy Logic Mamdani Programming Model in the Dizma Koi Blitar Business. This research aims to choose the most optimal supplier by minimizing the number of defects and the purchase price for the Dizma Koi Blitar business.

2. Material and methods

2.1. Research design

This study uses a quantitative descriptive type of research that focuses on data analysis in the form of numbers whose results are described in a condition as a basis for problem-solving [9].

2.2. Data Types and Sources

The type of data needed in this research is quantitative data in the form of numbers that can be calculated and measured mathematically. Quantitative data in this study are the price of fish products and the expected ratio of product defects. The data sources are evidence of business transactions and books used for recording daily transactions [8,9] . The secondary data needed in this study are sales data, fish product prices and product defects.

2.3. Data analysis method

The data analysis method used in this research uses the Mamdani type fuzzy logic method. Determining the quality of this supplier uses fuzzy decision-making using several pre-arranged inputs.

3. Results and discussion

3.1. Research Results of Supplier Quality Measuring Instruments

The research results on measuring the quality of koi fish suppliers provide the calculation of two different predictive data sets; the first forecast uses two input factors, while the second uses five input variables. The two projections are close to the results of the first fish purchase. The prediction of fish purchases is target for every month in 2021. A comparison of MAPE and MSE values has been arranged in a table to make it easier for researchers to assess the model's accuracy. [10, 11, 12] MAPE and MSE values are needed to select the prediction data most similar to the original. The results of this study are in the form of a measuring tool for assessing the best-chosen suppliers seen from the two factors of input price variables and defective products. The following is a display of the Matlab GUI results:

Figure 1 GUI Display Matlab Supplier Quality Determination Program

Figure 1 above shows a program trial using an input price of Rp. 415,000.00 with ten defective products in one bag. Based on the use of the two input variables, it turns out that the prediction result of the supplier quality value is 2,5282. If converted, the supplier is in the excellent category because at that price, it is included in the affordable category, and defective products are included in the low category. So that the quality of the supplier has an excellent value, therefore, Dizma Koi Blitar can decide on selecting the most optimal supplier to procure koi fish products, which will later be distributed to customers. When viewed using MAPE and MSE, the MSA value obtained is 2.3129. This shows the level of error in forecasting is minimal. To find out more about the model's accuracy in showing MSA, MAPE, and MAPE values, table 1 below.

Table 1 Comparison of MAPE and MSE Values with Different Input Variables

Actual	Prediction	MAD	MSE	MAPE
2	3	0.028	0.009184	1.1370
0.76	2.55	0.179	0.356011	7.0196
2.3	2.41	0.011	0.001344	0.4564
0.21	0.24	0.003	0.0001	1.2500
0.11	0.15	0.004	0.000178	2.6667
0.16	0.19	0.003	0.0001	1.5789
0.21	0.24	0.003	0.0001	1.2500
0.231	0.243	0.001	0.000016	0.4938
0.31	0.35	0.004	0.000178	1.1428

3.2. Creating Universal Sets

The universal set or the universe has a value limit used in the fuzzy set variable. The fuzzy set variable in this study is koi fish sales data. The universe talks on the data that is the range between 210,000 to 980,000 (per bag) for the price. While the range is between 3 to 45 (per bag) for defective fish products. So the universal set of fish supplier data is Uprice = [210,000, 980,000] and Udefect = [3.45].

Determining the Fuzzy Set

Based on the results of giving koi fish, it is divided into fuzzy sets, namely:

3.2.1. Price Set

The set for prices is divided into 5 classifications, namely Cheap (M), Affordable (Th), Normal (Nh), Expensive (Mh), and Very Expensive (SM).

3.2.2. Defective Product Set

The set for defective products is divided into 5 classifications, namely Very Low (SR), Low (R), Medium (Mp), High (Tp), Very High (ST)

3.2.3. Expected Supplier Quality Set

The set for the expected supplier quality is divided into 5 classifications, namely Very Bad (SB), Bad (B), Normal (Nk), Good (B), and Very Good (SB).

3.3. Determining the Membership Function

The membership function for each fuzzy set will be represented using a triangular curve as follows:

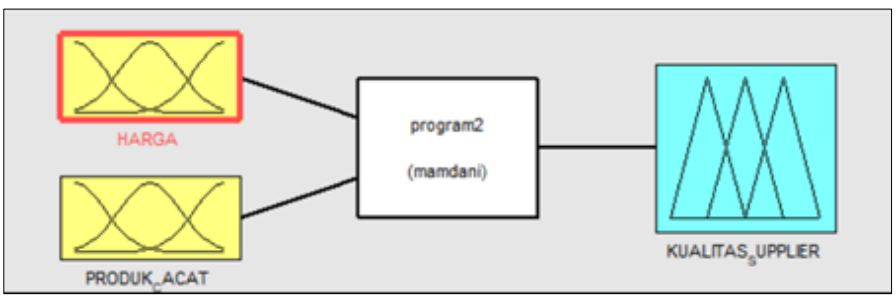


Figure 2 Graph of Membership Functions in the Universal Set

3.4. Fuzzyfication Process (Assertion)

After going through the membership function process, the next step is to confirm the process details as follows:

3.4.1. Price Linguistics

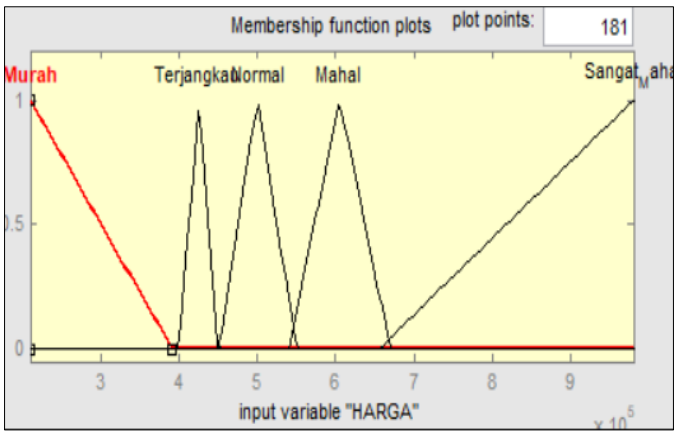
The linguistic fuzzy logic of price variables is classified into 5 categories as follows:

Table 2 Lingistic Classification Price per Bag Loyal Times Wholesale

No	Linguistik Value	Interval (Idr)
1	Cheap	< 210000
2	Affordable	210000-450000
3	Normal	450000-550000
4	Expensive	550000-670000
5	Very Expensive	> 670000

Based on the table above, it can be seen that there are 5 kinds of linguistic values of the Mamdani fuzzy, to see the representation in graphical form, it can be seen in the image below.

Table 3 Price Linguistic Function Chart



Based on the graphic image, the membership function can be expressed with a mathematical calculation as follows.

$$\mu_{cheap} = \{1;\ x < 210.000$$

$$\mu_{Affordable} = \begin{cases} \dfrac{x - 400.000}{25.000}; & 400.000 \leq x \leq 425.000 \\ \dfrac{450.000 - x}{25.000}; & 425.000 \leq x \leq 450.000 \end{cases}$$

$$\mu_{Normal} = \begin{cases} \dfrac{x - 450.000}{50.000}; & 450.000 \leq x \leq 500.000 \\ \dfrac{550.000 - x}{50.000}; & 500.000 \leq x \leq 550.000 \end{cases}$$

$$\mu_{Expensive} = \begin{cases} \dfrac{x - 540.000}{65.000}, & 540.000 \leq x \leq 605.000 \\ \dfrac{670.00 - x}{65.000}; & 605.000 \leq x \leq 670.000 \end{cases}$$

$$\mu_{Very\ Expensive} = \{1;\ x > 670.000$$

3.5. Defective Product Linguistics

Defective products are used as a reference to determine supplier quality. This is done because every item ordered has a number of fish that are defective, causing losses for the business owner. Therefore, defective products are used as a reference to determine supplier quality.

Table 4 Linguistic Classification of Defective Products per Bag Each Time Wholesale

No	Linguistik Value	Interval (fish)
1	Very Low	< 12
2	Low	12-21
3	Middle	21-24
4	Higher	25-34
5	Highest	> 34

Based on the table above, it can be seen that there are 5 kinds of linguistic values of fuzzy mamdani. The value of the interval can be represented in the form of a graph as follows.

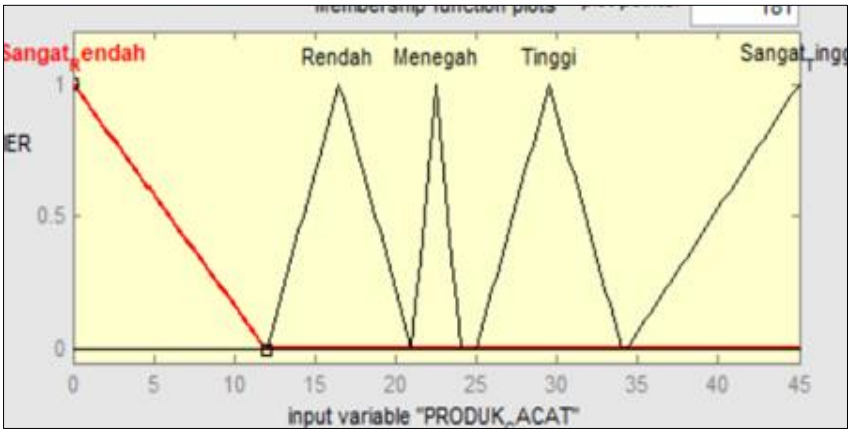


Figure 3 Linguistic Functions of Defective Products

$$\mu_{verylow} = \{1;\ x < 12$$

$$\mu_{Low} = \begin{cases} \dfrac{x-12}{9};\ 12 \le x \le 15 \\ \dfrac{21-x}{9};\ 15 \le x \le 21 \end{cases}$$

$$\mu_{Middle} = \begin{cases} \dfrac{x-21}{1{,}5}; 21 \le x \le 22{,}5 \\ \dfrac{24{,}5-x}{1{,}5};\ 22{,}5 \le x \le 24 \end{cases}$$

$$\mu_{high} = \begin{cases} \dfrac{x-25}{4{,}5}; 25 \le x \le 25{,}5 \\ \dfrac{34-x}{4{,}5};\ 25{,}5 \le x \le 34 \end{cases}$$

$$\mu_{veryhigh} = \{1;\ x > 34$$

3.5.1. Supplier Quality Linguistics

Supplier quality is the desired output for forecasting the two inputs above, namely prices and defective products. The following is supplier quality linguistics.

Table 5 Linguistic Classification of Supplier Quality

No	Linguistic Value	Interval
1	Very Bad	< 0,22
2	Bad	0,22 – 0,32
3	Normal	0,32 – 1
4	Good	1 – 3
5	Very Good	> 4

Based on the table above, it can be seen that the linguistic value of fuzzy Mamdani has 5 categories ranging from very bad to very good. The linguistic value until the calculation of the acquisition of the interval is generated using the formula processed by the business owner Dizma Koi Blitar which is represented as follows:

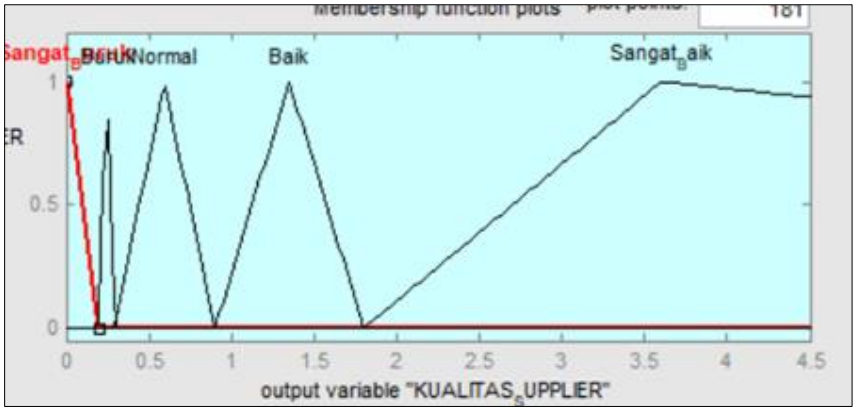


Figure 4 Supplier Quality Linguistic Function

3.6. Developing Mamdani's Fuzzy Inference System (FIS) in Matlab

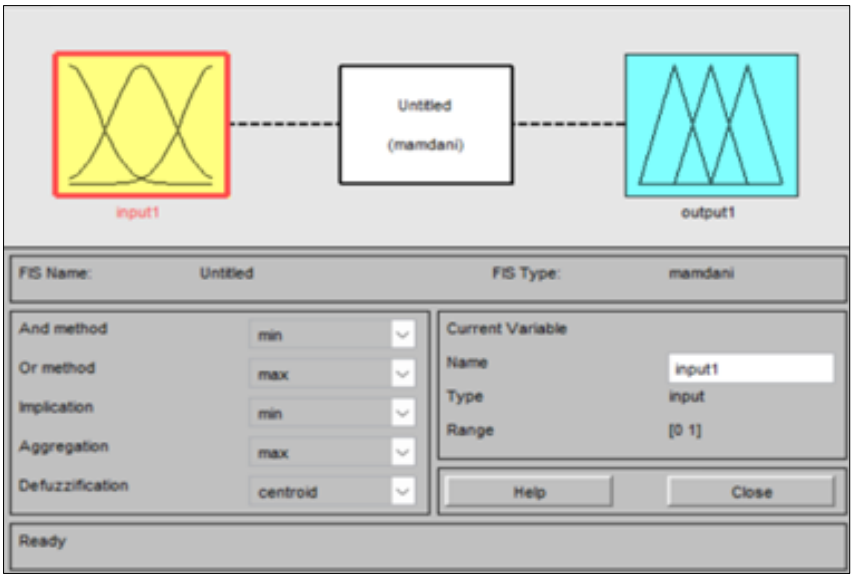


Figure 5 FIS Editor in the Matlab Toolbox

The next step is to enter the input data into the Matlab software toolbox. This view can be seen by typing the fuzzy menu in the Command Window display of the Matlab program and then pressing Enter. The display will look like in Figure 5 above.

This image shows a Fuzzy Inference System (FIS) editor using an approach based on the Mamdani fuzzy method, as shown in Figure 2. This approach was chosen because it has two advantages; first, the input design can be changed quickly, allowing changes from fuzzy sets to be implemented and accessible; second, the calculation is more straightforward [10,13,14].

3.7. Calculating Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE)

Mean Squared Error (MSE), or mean squared error, is an additional metric that can be used to evaluate different forecasting systems. Each error or remainder is assigned a squared value. After that, we add them all up and add them to the total number of observations. This approach results in intermediate errors, which, while preferable to small ones, can sometimes have a significant impact. The following formula, derived from Wei (1990), can be used to calculate the mean squared error of any feasible model:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(x_i(t) - y_i^*)^2$$

with:

n = Number of data
xi (t) = i-th data output
yi* = i-th output prediction

Mean Absolute Error (MAPE) is calculated using the absolute error in each period divided by the actual observed value for that period. Then, average the absolute percentage error. This approach is practical when the size or magnitude of the forecast variable is essential in evaluating the accuracy of the forecast. MAPE indicates how big the forecast error is compared to the actual value. Selection of the best model through the Out Sample approach based on error using MAPE. With the following equation (Wei, 1990):

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|A_i - F_i|$$

n = sample size
Ai = ii-th actual data value
Fi = value of the-ii forecast data

The formula above is used to determine the MSE and MAPE values for both data, namely training data and testing data. The calculation is as follows:

$$MSE = \frac{1}{n}\sum(x(t) - y*)^2$$

$$= \frac{1}{10}x\ 0.0827$$

$$= 0.00918$$

$$MAPE = \frac{1}{n}\sum|x(t) - y*|$$

$$= \frac{1}{10}X\ 0.288$$

$$= 1.137$$

We compare data on purchasing fish seeds with predictions for purchasing fish seeds using two input variables. The calculation is done using a model with two input variables, namely x (t-2) and x (t-1), using the same approach, especially the Mamdani method, to serve as a comparison.

4. Conclusion

Mamdani approach and Fuzzy Inference System (FIS) are used to predict the output of supplier quality determinants at Dizma Koi Blitar. Only data from Koi sellers, with monthly intervals from 2022, were used as input in this study. The following are some conclusions that can be drawn from this research:

1. The fuzzy modeling steps of the Mamdani method are: determining input and output based on purchase data to supplier Dizma Koi Blitar; determining the universe of speech (universal set); creating fuzzy sets; defining membership function; selection of fuzzy rules based on training data; make fuzzy model Mamdani method with Matlab software; testing fuzzy models on training data and testing data, determining the level of model accuracy based on MAPE and MSE values; predict supplier quality.

2. The error rate (MAPE) obtained by the experimental results in table 4.7 shows a value of <10%. This proves that the prediction results from determining the supplier's quality are accurate and can be applied. Thus, Dima Koi Blitar can use this software to determine the quality of suppliers and the progress of their business.

Compliance with ethical standards

Acknowledgments

The authors thank the reviewers for their insightful suggestion.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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