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Fuzzy Inference System Tsukamoto for Decision Making in Ordering Goods (Building Materials)

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***Abstract*—Decision making recommendation system in this research aims to determine the amount of the building materials that must be available to meet the needs of the construction of housing projects. Calculating the right amount of the building materials is very important in a project, because it determines the amount of the budget to be made by a building contracting company. This decision making is useful to determine the amount of the building materials that must be available based on inventory data and the number of requests using Tsukamoto Fuzzy Inference System. Decision making in this study was modeled with three variables. Each variables consists of 3 fuzzy sets. The amount of inventory in this system is determined by the centralized average defuzzification method. The proposed method can predict precisely the amount of the building materials. The accuracy of the test data is shown based on the MSE obtained from the prediction results. Based on the calculation of the error can be concluded that the actual order at the company compared to the calculation using Tsukamoto FIS had an error of 0.11505. So it can be concluded that the method in this system can work well and has high accuracy.**

Keywords*—*Tsukamoto fuzzy interference system, decision making in ordering goods of building materials, mean squared error (MSE)

I. INTRODUCTION

The problem faced by a real estate development company today is the difficulty in determining the amount of building materials to be purchased. Deficiency or excess building materials often occur because of manual calculation errors of building materials. Therefore, the company needs a system to predict the needs of building materials in a real estate project so that proper budget planning can be done.

Fuzzy logic is a method in the decision-based decision making process that aims to solve an uncertain problem [1,2]. There are several methods used to present the results of fuzzy logic, including fuzzy tsukamoto, mamdani, sugeno [3]. One application of fuzzy logic is the use of fuzzy inference systems in determining the items that must be available. The number of factors involved in the calculation becomes an obstacle for decision makers in determining the policy of the amount of goods to be produced. These factors are: maximum demand for a certain period, minimum demand for a certain period, maximum supply for a certain period, minimum inventory for a certain period, maximum production for a certain period, minimum production for a certain period, current demand, and current inventory. For this reason, a method is needed to solve this problem.

A decision support system using fuzzy logic with the Tsukamoto method can be the best solution to problems faced by housing developers. This proposed model can be used to support decision making in determining the prediction of the amount of building material to be purchased based on the results of accurate data calculations. Accurate predictions for building material inventory decisions are needed to compile the company's financial budget. If the ordered items are not used based on the time of use, the goods will make the warehouse full. One solution is to build a decision support system that can predict the number of items that must be ordered. A good approach is needed to determine models with accurate predictions. This study applies the Tsukamoto Fuzzy Inference System to solve this problem.

The problem of decision making based on many parameters and uncertain information makes it difficult to solve. The number of variables is increasingly large and difficult, or it is impossible to solve it manually to achieve the optimal solution [3,4]. Fuzzy logic provides a way to measure, and handle lots of uncertain data. Fuzzy logic states that nothing can be firmly stated as completely true or completely false. The main purpose of a fuzzy logic system or inference is decision making.

Several studies have applied fuzzy logic for make a decision. Priyono and Surendro [5] in their research using fuzzy logic to model and calculate the suitability and calorie requirements of food and users. Mishra [1] has conducted research on multi-criteria decision making problems in web recommendations. the built system has been modeled using a fuzzy approach. Important product parameters have been stated in linguistic way. The fuzzy approach is relevant and useful in the quantification of linguistic variables. Similar research has been conducted by Gupta and Muhuri [6] using the fuzzy approach method to solve the multi-objective linguistic optimization problem.

One application of fuzzy logic is the use of fuzzy inference systems in prediction. Heidari et al. [7] in their research predicting weather conditions on stone monuments in Iran. Tsukamoto fuzzy inference system used by Hastono et al. [8] to predict honey yield. There are use 3 input fuzzy in their study. Similar research was carried out by Wahyuni et al. [9] to predict rain in the Tengger area of Indonesia. In addition to the recommendation system or decision making, Tsukamoto Fuzzy Inference System is also used to build expert systems. Suharjito et al. [10] in their research using Fuzzy Tsukamoto to build an expert system to help diagnose the level of risk in cows based on 6 clinical symptoms.

II. Methods

Fuzzy Inference System (FIS) is a series of logic and fuzzy with IF-THEN models, wrapped in computing. Before sending input with IF-THEN fuzzy rules, FIS must get fresh input. Aggregation will be done if there is more than one rule. The aggregation value must be defuzzy so that a crisp output is obtained. Fuzzy Logic has 3 stages as follows: (a) Fuzzification which is also called blurring: in a set of fuzzification input mapping is done, (b) Fuzzy Inference System: produce rules called fuzzification, and (c) Defuzzification : output in the form of fuzzification is changed to solid form. Various kinds of information that can be linked to other information in the framework of knowledge structure, produce conclusions called rules. IF contains rules as a link between places, while THEN as a link between conclusions. In a rule, have at least one premise. The premise can be obtained from the relationship of conjunction statements (AND) and statements in the form of disjunction (OR). The premise is also allowed as a combination of both [11].

In Tsukamoto's method, each rule must have monotonous reasoning, which in the system has only one rule. The system has several rules in the Tsukamoto method. This is due to the existence of monotonous reasoning in the basic concept, soth at there are consequences for all IF-THEN rules must be a representation of the fuzzy set of monotonous membership. Explicitly based on α-predicate, the output of each rule is given (crisp). The final results are obtained based on the concept of a weighted average on the use of defuzzy, after previously carried out aggregation between rules [9].

III. Results and Discussion

In developing this decision support system, data and information is identified to support it. Identification data for cement building materials, because cement is the majority used building material. For real estate development projects, the order cycle for cement is very high. If the developer is late in an order or incorrectly determines the number of orders, it will greatly affect the efficiency and effectiveness of the company. In this study, we propose a decision making model using a fuzzy inference system. The model is shown in Figure 1.

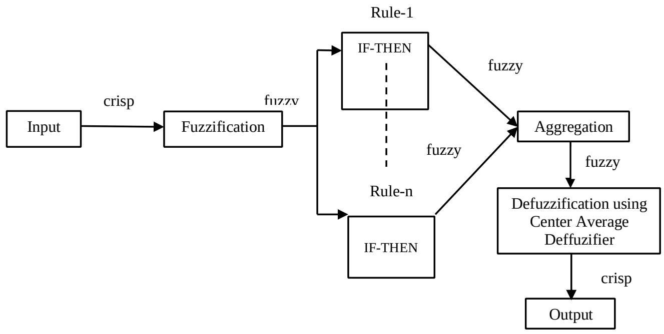

Fig. 1. The proposed model.

A. *Fuzzification*

In the fuzzification process, the membership function for each fuzzy variable uses the linear ascending, descending and triangular function approach. In this case there is a stock of 800 and a usage of 900 packages

Usage input variable. Monthly cement usage data is one of the fuzzy variables in this decision support system. This variable has a range [0-2000] with several sets.

Membership function:

$$\mu_{\text{low usage}}[x] \quad \{ 1, x \le 750 \ \frac{(1250-x)}{(1250-750)}, 750 \le x \le 1250 \ 0, x \ge 1250 \qquad (1)$$

$$\mu_{\text{moderate usage}}[x] \quad \{ 0, x \le 750 \text{ or } x > 2000 \ \frac{(x-750)}{(1250-750)}, 750 \le x \le 1250 \ \frac{(2000-x)}{(2000-1250)}, 1250 \le x \le 2000 \qquad (2)$$

$$\mu_{\text{a lot of usage}}[x] \quad \{ 0, x \le 1250 \ 1, x \ge 2000 \ \frac{(x-1250)}{(2000-1250)}, 1250 \le x \le 2000 \qquad (3)$$

Membership value in fuzzy set for usage input variable of 800 packages: $\mu_{\text{low usage}}[800] = 0.7$; $\mu_{\text{moderate usage}}[800] = 0.3$; $\mu_{\text{a lot of usage}}[800] = 0$

Inventory input variable. Membership function of the inventory input variables:

$$\mu_{\text{slight inventory}}[y] \quad \{ 1, y \le 1000 \ \frac{(1000-y)}{(1000-500)}, 500 < y < 1000 \ 0, y \ge 1000 \qquad (4)$$

$$\mu_{\text{moderate inventory}}[y] \quad \{ 0, y \le 500 \text{ or } 0, y \ge 1500 \ \frac{(y-500)}{(1000-500)}, 500 \le y \le 1000 \ \frac{(1500-y)}{(1500-1000)}, 1000 \le y \le 1500 \qquad (5)$$

μ many inventory [y] $\{ 0, y \leq 1000\ 1, y \geq 500\ \frac{(x-1000)}{(1500-1000)}, 1000\ \leq y \leq 1500$ (6)

Membership value in fuzzy set for inventory input variable of 900 packages : μ slight inventory [900] = 0.4 ; μ moderate inventory [900] = 0.6 ; μ many inventory [900] = 0

Purchasing input variable. Membership function of the purchasing input variables:

μ a little purchase [z] $\{ 0, z \geq 600\ \frac{(600-x)}{(600-300)}, 300\ < z \leq 600\ 1, z \leq 300$ (7)

μ moderate purchase [z] $\{ 0, z \leq 300\ or\ z \geq 900\ \frac{(z-300)}{(600-300)}, 300\ \leq z \leq 600\ \frac{(900-x)}{(900-600)}, 600 \leq z \geq 900$ (8)

μ many purchase [z] $\{ 0, z\ \leq 600\ 1, z\ \geq 900\ \frac{(z-600)}{(900-600)}, 600\ \leq z < 900$ (9)

B. Inferences

The management process for procurement of building materials uses 9 rules. Then combining all rules of all events. Fuzzy calculation uses the minimum of the membership value. The rules used in fuzzy calculations involving fuzzy membership values are shown in the equation below:

- [Rule 1] If usage is low and inventory is many then ordering is less. In the fuzzy rule, P1 is symbolized as α-predicate for rule 1.

  P1 = min (0.7, 0) = 0

  Then based on the purchasing set decreases, so the value Z1 = 0
- [Rule 2] If usage is down and inventory is moderate then ordering is less. In Fuzzy rule, P2 is symbolized as α-predicate for rule 2

  P2 = min (0.7, 0.6) = 0.6

  Then based on the purchasing set decreases, so the value Z2 ; Z2 = (600 – z)/300 = 420
- [Rule 3] If usage is down dan inventory is slight then ordering is less.

  P3 = min (0.7, 0.4) = 0.4 ; Z3= 480
- [Rule 4] If usage is moderate and inventory is many then ordering is less.

  P4 = 0 ; Z4 = 0
- [Rule 5] If usage is moderate and inventory is moderate then ordering is constant

  P5 = min (0.3, 0.6) = 0.3 ; Z5 = (z - 300)/300 = 390
- [Rule 6] If usage is constant and inventory is slight then ordering is increased

  P6 = min (0.3, 0.4) = 0.3 ; Z6 = (900 – z)/300= 810
- [Rule 7] If usage is many and inventory is many then ordering is increased

  P7 = 0 ; Z7 = 0
- [Rule 8] If usage is many and inventory is moderate then ordering is increased

  P8 = 0 ; Z8 = 0
- [Rule 9] If usage is many and inventory is slight then ordering is increased

  P9 = 0 ; Z9 = 0

C. Defuzzification

Defuzzification is the process of obtaining crisp values from fuzzy values. The method used in the defusification process for Fuzzy Tsukamoto is the center average defuzzifier.

$$z = \frac{(P1.Z1)+ (P2.Z2)+ (P3.Z3)+ (P4.Z4)+ (P5.Z5)+ (P6.Z6)+ (P7.Z7)+ (P8.Z8)+ (P9.Z9)}{(P1+P2+P3+P4+P5+P6+P7+P8+P9)} = \frac{894}{1.6} = 558.75 \quad (10)$$

So, the number of cement purchases next month is 559 packages.

D. Result validation

The accuracy of the test data can be seen based on the MSE obtained from the prediction results. MSE is a method for analyzing or measuring data errors. The MSE method is used to validate the proposed fuzzy inference system model that has good accuracy. The MSE equation is shown in equation (3).

$$MSE = \frac{1}{n} \sum_{i=1}^{n} (y - y`)^2 \quad (11)$$

where y` is a prediction data, y is actual data and n is the number of data.

In this study, the MSE method was used to determine the results of the calculation of the crisp value in the fuzzification process. The results of comparisons of the Tsukamoto method for monthly cement ordering data are presented in Table 1.

TABLE I. COMPARISON OF THE RESULTS OF THE PROPOSED METHOD AND THE REALITY OF THE DATA

Month	Prediction (Y`)	Actual (Y)	Difference	Square Difference
1	540	523	-0.17	0.0289
2	523	500	0.23	0.0529
3	548	556	-0.08	0.0064
4	655	649	0.06	0.0036
5	505	555	-0.5	0.25
6	550	520	0.3	0.09
7	645	580	0.65	0.4225

8	587	612	-0.25	0.0625
9	600	612	-0.12	0.0144
10	627	610	0.17	0.0289
11	501	630	-0.29	0.0841
12	570	512	0.58	0.3364

From table 1 it can be seen that the prediction using the proposed method (Tsukamoto fuzzy inference system) compared to the fact that the cement demand every month has an error of 0.11505 This means that the decision making method can be applied in this case, and the level of validity is high because the error is worth below 1.

IV. CONCLUSION

In this study, Tsukamoto fuzzy inference system proposes for decision making to purchase building materials (cement). Some conclusions from the application of the method in this study. In applying the Tsukamoto Fuzzy Inference System (FIS) method to determine the number of ordering goods, there are 3 steps that are performed: arranging membership and determine the fuzzy rules, inference, determine the output crisp. The results of the system calculation do not much different with the calculation results that are done by manually. This is proven by information in the table of Mean Squared Error (MSE) with error results of under 1 (had an error of 0.11505). So it can be concluded that the method in this system can work well and has high accuracy.

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