

Fuzzy Tsukamoto based Decision Support Model for Purchase Decision in Pharmacy Company



Guroh Kharisma Ramadhan, Ditdit Nugeraha Utama

Abstract: *The difficulty in determining a number of item purchased is one of essential activities in inventory management. This study scientifically proposes a decision support model to decide how much number of next item purchased by a pharmacy company. The main objective of the developed model is to control a minimum stock at a certain time and condition and support in making the decision on how many items should be purchased at next time. Decision support model considers two independent parameters; lead time and stock. Tsukamoto's fuzzy system is functioned in this study to avoid blurring parameter values from someone making a decision. Each criterion is divided into three membership functions; with nine fuzzy-rules used. The model also supports changing parameters if parameter values are changed. Based on the results of model test done, the optimized number of item purchased at the Pharmacy Company is able to be proposed practically.*

Keywords: *Inventory management, purchase, fuzzy logic, Tsukamoto, Pharmacy.*

I. INTRODUCTION

Purchasing is an imperative activity carried out by companies and organizations in fulfilling inventory. Today, having the right and accurate inventory of item is required, exclusively in large scale companies that have a lot of items. According to [1], purchasing is an organization's way providing a continuity of supply for the customers. To make good procurement decisions, organizations need an accurate and reliable data. Making a purchase based on inaccurate data and uncertainty is able to trigger inventory shortages, excess inventory, and other costs that harm the company.

Fifty-four years ago, in 1965, [2] introduced the fuzzy set theory to overcome the inaccuracies and uncertainties inherent in human judgment in the decision making process through the use of linguistic terms and membership levels. Fuzzy set is an object class with membership value. These values present a level of stability where certain elements become part of the fuzzy set. And one method in representing the results of fuzzy logic is the Tsukamoto fuzzy inference

system (FIS).

The Tsukamoto method is operated academically in many areas; such as student financial service [3]. In this area, the Tsukamoto model was used to determine which students receive a discount on school fees by looking at the factor of how much income parents have and the number of children covered. The results of this study were that many scholarship rates depended on the economic level of parents and the GPA for these students but due to data the number of students who received scholarships was small, so the difference without or using Tsukamoto was different from each student about 1,000-15,000.

In the human resource area, [4] were the next researchers who operated the Tsukamoto FIS method to solve the problem in the recruitment and selection process of prospective employees. Furthermore, the researchers used the academic GPA value and the APT results of the prospective employee as parameters; where previously only one parameter functioned.

In the retail industry area, [5] functioned the fuzzy Tsukamoto method to help in making decisions regarding how many numbers of items the company needed to order. Three variable parameters used (i.e. sales, inventory, and ordering or purchasing) for research. The results of the study using FIS have better and efficient results in predicting the number of ordering goods in retail companies.

In the area of agriculture, [6] operated the Tsukamoto fuzzy method to determine the amount of production applied in the decision support system (DSS), then the DSS was going to process the data using the Tsukamoto method and display the output in the form of the amount of goods to be produced. Based on the results of testing the accuracy of the error value obtained from the results of a small forecasting of 0.0607%. The results given by the fuzzy Tsukamoto method were in accordance with the results of the data from PT. GGC with an error value of 0.0607%.

From some background points above, the research on decision making using the Tsukamoto FIS method is important to be studied in depth. The results of this study are expected to later support in controlling the decision on how many items purchased in Pharmacy Company should be made.

II. LITERATURE REVIEW

In this section, the researcher conducted the first review of the importance and complexity of decision making to determine the number of purchases for each business was reviewed. Here, many factors that can be influencing; e.g. inventory and sales levels. [5]

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* Correspondence Author

Guroh Kharisma Ramadhan*, Computer Science Department, BINUS Graduate Program – Master of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480.

Ditdit Nugeraha Utama, Computer Science Department, BINUS Graduate Program – Master of Computer Science, Bina Nusantara University, Jakarta, Indonesia 11480.

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proposed the FIS with the Tsukamoto method to calculate the amount of goods purchased. Three variables were used in this study; namely sales, inventory, and ordering or purchasing.

Data was tested using a system in order to save time in determining the number of aggregation which then multiplied by the safety stock data so that the number of purchased is obtained. The results of the study produced a comparison between the proposed method and the manual forecast having an error value of 0.20815 which can be concluded that the method works well and can be used as a research object. However, due to the limitations of the variables used, the researchers proposed to add more than 3 input variables so that they got better results.

In addition, [7] conducted a study to determine the economic order quantity (EOQ) and the implementation of the order by proposing DSS based on the adaptive neuro fuzzy inference system (ANFIS). Input parameters namely size of demand, inventory level, and price were used as rules of EOQ models. Based on the test results, the proposed method was good and effective can be used as a tool for planning in SCM and has been systematically tested. However, because the ANFIS model training time relies on large historical data and repetitive training, it makes the application unusable.

A. Fuzzy Logic

Basically, fuzzy logic is used to eliminate, reduce partial value parameter [7] and avoid blurring when someone makes a decision to remember from all the available information and make the best choice from the input given [8]. Furthermore, fuzzy logic has two concepts namely firm logic and fuzzy logic. Strict logic only recognizes two conditions, namely: yes or no, high or low, 1 or 0. Whereas fuzzy logic is a disguised logic whose degree of truth is between (0, 1). The reasons for using fuzzy logic are as follows: (a) easy to understand, because mathematical set theory as a basis for fuzzy is easy to understand, (b) flexible for modification and uncertainty problems [9], (c) accepting data that is less precise, and (d) using language that is easy to understand. The two attributes possessed by the fuzzy set are as follows [10]: a) linguistics just call it a set of everyday language uses to replace under certain conditions, For example HIGH, MEDIUM, LITTLE replaces variable volume; b) numerical: a number that indicates a variable parameter, for example 1, 7, 14 and others (Fig.1).

In fuzzy set theory, the role of the degree of membership as a determinant of the existence of elements in a set is very important. The value of membership or the degree of membership or membership function becomes the main characteristic of reasoning with fuzzy logic [10]. One example is mapping an input output in graphical form as shown in the Fig. 2.

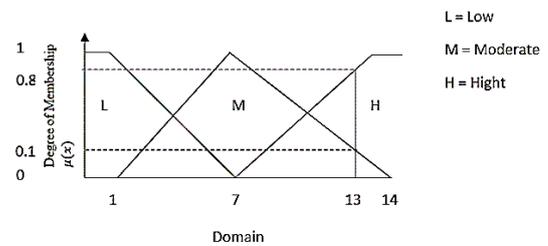


Fig. 1. Degree of Membership

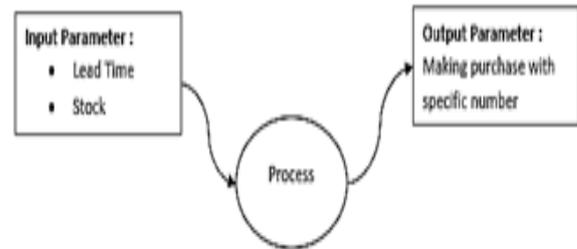


Fig. 2. Example mapping Input-Output

B. Tsukamoto Method

FIS is a computational framework based on fuzzy set theory, IF-THEN fuzzy rules, and fuzzy reasoning. So far, several methods have been well-known in the FIS; such as the Tsukamoto, Mamdani and Sugeno. In the Tsukamoto method, each consequence of an IF-THEN rule must be represented by a fuzzy set with a monotonous membership function. The inference output from each rule is given explicitly (crisp) based on α -predicate (fire strength). The final result uses a weighted average [11].

C. Decision Support Model

Decision making is an important part of any business, so this model should be considered a valuable part of a company's operational activities. Where the success of the decision produces profits, while unsuccessful results in losses. Steps in the decision making process are configured in Fig. 3.

Step 1, this stage begins by analyzing the problem. The interview method is used to identify the purpose of the decision. In Step 2, a problem can be related to many stakeholders' needs and can have many factors involved and influential. Step 3, at this stage, the basic criteria for selecting parameters must be based on the vision / mission of the company. Profit is one of the main concerns in every decision making. Step 4, at this stage analyze several options using several tools. Cause effect diagram tools and Pareto tools are used in this stage. Step 5, use assessment principles and decision making criteria to evaluate each alternative. One alternative with other alternatives compared to get positive and negative each alternative. Step 6, at this stage select the best alternative. Step 7, run the planned decision in the sequence of activities. In Step 8, the results that have been carried out are evaluated and continuous improvements are made in order to get even better results.

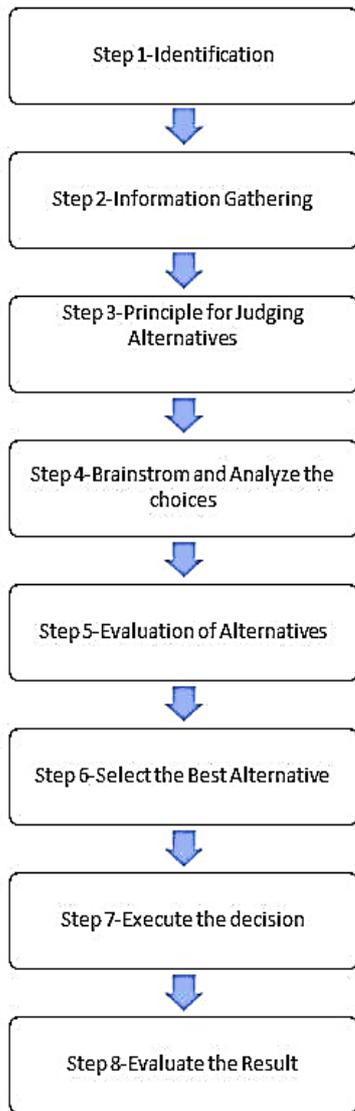


Fig. 3. Stage Decision Making Process

III. RESEARCH METHODOLOGY

In achieving decision support model (DSM) for purchasing, it must be followed by determining the estimated inventory system parameters. Where the next stage of inventory optimization is obtained by creating the smallest stock (minimum stock) at a certain time or condition. The method used is a quantitative approach in pharmacy X, with the following research steps.

A. Data Collection

Data collection is the process of gathering information from all relevant sources to find answers to research problems, test hypotheses and evaluate the results. The data that we do is by interviewing experts who are directly involved in the inventory management process. The results of our interviews are used as preliminary data on procurement consideration criteria that affect inventory management.

B. Stages

The research will be divided into several stages illustrated in Fig. 4.

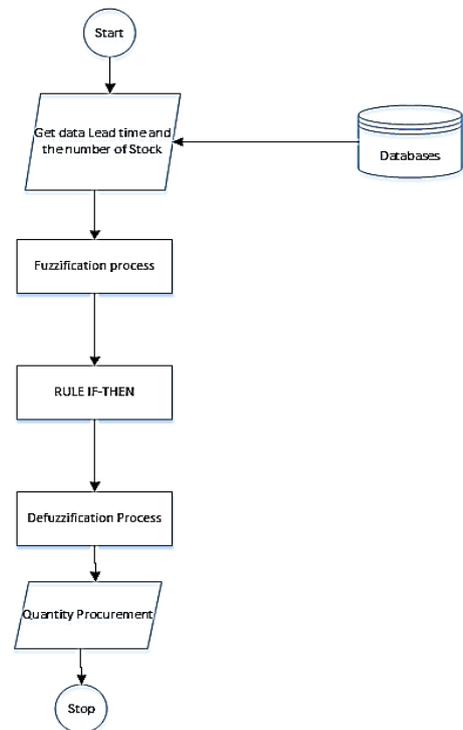


Fig. 4. Complete Stage of Study

Table- I. Example Lead Time (Lt), Stock (St), Safety Stock (SS)

Product Name	Lt	St	SS
A1	13	180	80
A2	6	111	40
A3	2	202	100
A4	4	38	25
A5	5	252	10
A6	14	250	80
A7	17	248	25
A8	4	190	24
A9	5	33	5
A10	1	78	10
A11	6	90	10
A12	7	101	15
A13	8	200	20
A14	4	300	20
A15	3	320	25
A16	3	402	25
A17	4	56	25
A18	5	101	20
A19	7	300	30
A20	4	289	30

In the first stage, it starts by collecting data and then generating input and output parameters from the items purchase dataset. The first input variable used in this study is Lead Time (Lt) criteria (Fig. 5) which has the fuzzy SHORT, MODERATE, and HIGH categories.

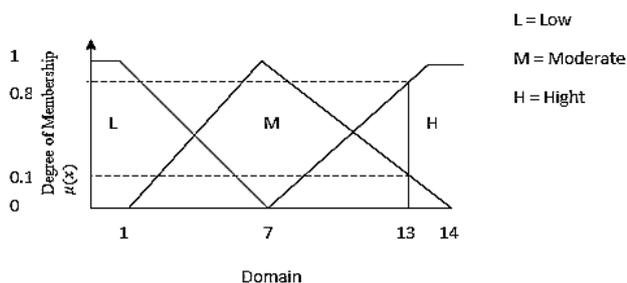


Fig. 5. DOM Lead Time

The membership functions of each set are summarized in equations 1, 2 and 3.

$$\mu_{Lt Short}(x) = \begin{cases} 0, & x \geq 7 \\ 1, & x \leq 1 \\ \frac{7-x}{7-1}, & 1 < x < 7 \end{cases} \quad (1)$$

$$\mu_{Lt Moderate}(x) = \begin{cases} 0, & x \leq 1 \text{ or } x \geq 14 \\ 1, & x = 7 \\ \frac{x-1}{7-1}, & 1 < x < 7 \\ \frac{14-x}{14-1}, & 7 < x < 14 \end{cases} \quad (2)$$

$$\mu_{Lt Long}(x) = \begin{cases} 0, & x \leq 7 \\ 1, & x \geq 14 \\ \frac{x-7}{14-7}, & 7 < x < 14 \end{cases} \quad (3)$$

Where in equations 1, 2 and 3, μ is the degree of membership and x is the set of objects. The second input variable is STOCK (St) (Fig. 6). Has three (3) fuzzy set categories, namely LOW, MODERATE, HIGH.

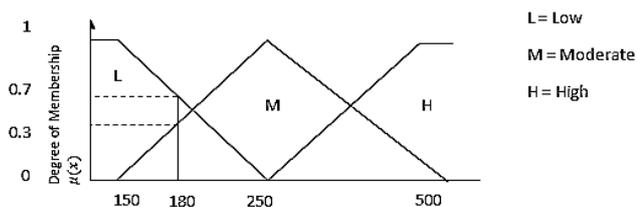


Fig. 6. DOM Stock

The membership functions of each set are summarized in equations 4, 5, and 6.

$$\mu_{St Low}(x) = \begin{cases} 0, & x \geq 250 \\ 1, & x \leq 150 \\ \frac{250-x}{250-150}, & 150 < x < 250 \end{cases} \quad (4)$$

$$\mu_{St Moderate}(x) = \begin{cases} 0, & x \leq 150 \text{ or } x \geq 500 \\ 1, & x = 250 \\ \frac{x-150}{250-150}, & 150 < x < 250 \\ \frac{500-x}{500-250}, & 250 < x < 500 \end{cases} \quad (5)$$

$$\mu_{St High}(x) = \begin{cases} 0, & x \leq 250 \\ 1, & x \geq 500 \\ \frac{x-250}{500-250}, & 250 < x < 500 \end{cases} \quad (6)$$

Where in equations 4, 5, and 6, μ is the degree of membership and x is the set of objects. The output variable used in this study is making purchase order. This variable has three (3) fuzzy sets: LOW, MODERATE, HIGH (Fig. 7).

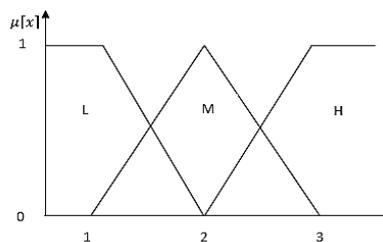


Fig. 7. DOM Purchasing (Prc)

The membership functions of each set are summarized in Equation 7, 8, and 9.

$$\mu_{Prc Low}(x) = \begin{cases} 0, & x \geq 2 \\ 1, & x \leq 1 \\ \frac{2-x}{2-1}, & 1 < x < 2 \end{cases} \quad (7)$$

$$\mu_{Prc Moderate}(x) = \begin{cases} 0, & x \leq 1 \text{ OR } x \geq 3 \\ 1, & x = 2 \\ \frac{x-1}{2-1}, & 1 < x < 2 \\ \frac{3-x}{3-2}, & 2 < x < 3 \end{cases} \quad (8)$$

$$\mu_{Prc\ High}(x) = \begin{cases} 0, & x \leq 2 \\ 1, & x \geq 3 \\ \frac{x-2}{3-2}, & 2 < x < 3 \end{cases} \quad (9)$$

Where in Equation 7, Equation 8, and Equation 9, μ is the degree of membership and x is the set of objects.

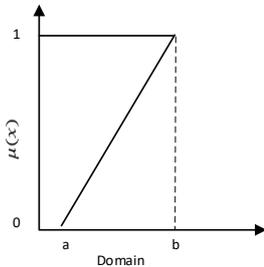


Fig. 8. Curve Rise

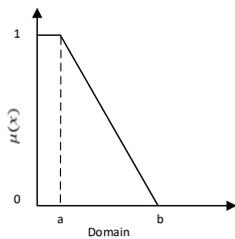


Fig. 9. Curve Down

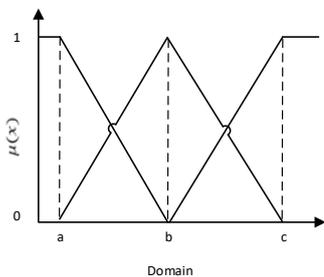


Fig. 10. Triangular Curve

Then the next stage of the fuzzification process or calculating the degree of truth (DOT). Membership function in each set is formulated in equations 10, 11 and 12.

$$\mu(x) = \begin{cases} 0, & x \geq b \\ 1, & x \leq a \\ \frac{b-x}{b-a}, & a < x < b \end{cases} \quad (10)$$

$$\mu(x) = \begin{cases} 0, & x \leq a \\ 1, & x \geq b \\ \frac{x-a}{b-a}, & a < x < b \end{cases} \quad (11)$$

$$\mu(x) = \begin{cases} 0, & x \leq a \text{ or } x \geq c \\ 1, & x = b \\ \frac{x-a}{b-a}, & a < x < b \\ \frac{c-x}{c-b}, & b < x < c \end{cases} \quad (12)$$

, after that it contains the IF-THEN rule base. In order to prediction number of items to purchase. There are 9 fuzzy rules will be used (Table- II):

Table- II. Examples of fuzzy rule base of the constructed model

[R1]	IF (Lt=SHORT) AND (St=LOW) THEN (Prc=HIGH)
[R2]	IF (Lt=SHORT) AND (St=HIGH) THEN (Prc=LOW)
[R3]	IF (Lt=SHORT) AND (St=MODERATE) THEN (Prc=LOW)
[R4]	IF (Lt=MODERATE) AND (St=LOW) THEN (Prc=MODERATE)
[R5]	IF (Lt=MODERATE) AND (St=HIGH) THEN (Prc=MODERATE)
[R6]	IF (Lt=MODERATE) AND (St=MODERATE) THEN (Prc=MODERATE)
[R7]	IF (Lt=HIGH) AND (St=LOW) THEN (Prc=HIGH)
[R8]	IF (Lt=HIGH) AND (St=HIGH) THEN (Prc=LOW)
[R9]	IF (Lt=HIGH) AND (St=MODERATE) THEN (Prc=MODERATE)

and enter a value into a rule base called inference, the next step is to calculate aggregation called defuzzification with each input variable and calculate the result of defuzzification (determine crisp output) (Fig. 11).

$$z = \frac{(\alpha_1 * z_1) + (\alpha_2 * z_2) + (\alpha_3 * z_3) + \dots + (\alpha_8 * z_8) + (\alpha_9 * z_9)}{(\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 + \alpha_7 + \alpha_8 + \alpha_9)}$$

Fig. 11. Aggregation

Process of fuzzification – defuzzification is coming from Fig. 12.

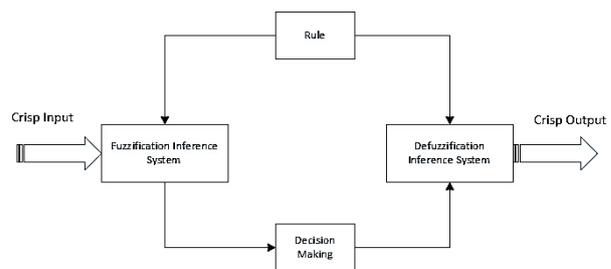


Fig. 12. Process Fuzzification – Defuzzification

IV. EXPERIMENTAL STEP AND METHOD

Some things that must be considered when calculating the optimization of ordering items using fuzzy with the Tsukamoto method, namely by regulating the membership / fuzzification function, determining fuzzy rules / rules, drawing conclusions and determining crisp output.

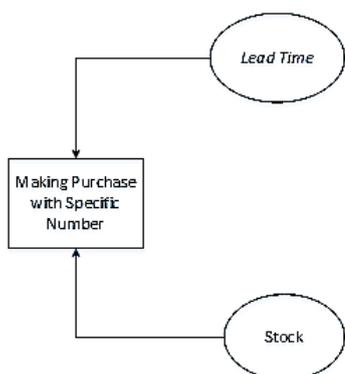


Fig. 13. Diagram of Decision Making Dependency

The decision made is in the form of making a purchase order (PO) with a certain amount. The decision to make a purchase is determined by two independent parameters, namely lead time and stock. (Fig. 13).

A. Fuzzification

In this study, the membership function for each fuzzy variable uses triangles, as an approach to get the value of the degree of membership in the fuzzy set. *Lead Input Variables* are divided into 3 categories: LOW, MODERATE, HIGH. The fuzzy set of DOWN membership function is linear down, fuzzy set CONSTANT membership function is triangle and fuzzy set RISE membership function is linear rise.

Furthermore, *Stock Input Variables* are divided into 3 categories: LOW, MODERATE, HIGH. The fuzzy group membership function LOW is linear, MODERATE the fuzzy group membership function is triangular and the HIGH fuzzy group membership function is linear. Membership functions in each set are summarized in Equation.

B. Inferences

Then all the rules are combined. This is done to get the fuzzy output value from the fuzzy input value. The mechanism is a fuzzy input value that starts from fuzzification and then is inserted into the rules that have been made fuzzy output.

Subjective values for parameter lead time (LT) is as follows:

- LT = Long Time, if $LT \geq 14$
- LT = Moderate, if $1 \text{ day} < x < 14 \text{ days}$
- LT = Short Time, $LT \leq 1$

Subjective values for parameter stock (St) is as follows:

- St = HIGH, jika $St \geq 500 \text{ item/month}$
- St = MODERATE, jika $150 \text{ item/month} < St < 500 \text{ item/month}$
- St = LOW, jika $St \leq 150 \text{ item/month}$

Subjective values for parameter purchasing (Prc) is as follows:

- Prc = HIGH, jika $Prc \geq 1$
- Prc = MODERATE, jika $1 < x < 3$
- Prc = LOW, jika $Prc \leq 0$

Table- III. Results Ri

		Lead time		
		S	M	H
Stock	L	0	0.08	0.86
	M	0.7	0	0.08
	M	0.3	0	0.08
	H	0	0	0

Table- IV. Result Zi

		Lead time		
		S	M	H
Stock	L		0.143	0.857
	M	0.7	2	2.7
	M	0.3	2	2
	H			

C. Defuzzification

To get the output value (crisp) is to convert inputs into numbers in the fuzzy set domain or defuzzification. After obtaining the value of α_i , then the value calculation process will be carried out for each consequent rule (Zi) in accordance with the membership function used. The defuzzification method in the Tsukamoto method is the Center Average defuzzification which is deflected by:

$$Z_1 = \frac{SUM(\alpha_i * z_i)}{SUM(\alpha_i)}$$

$$Z_1 = \frac{2.8}{1.154}$$

$$Z_1 = 2.42$$

And Then to get result of number of items purchased:

$$\text{Result} = SS * Z_1$$

$$\text{Result} = 80 * 2.42 = 194$$

Table- V. The overall result of the calculation of items purchased

Name	SUM ($\alpha_i * z_i$)	SUM (α_i)	Z	SS*Z
A1	2.80	1.15	2.42	194
A2	2.03	1.00	2.03	81
A3	2.63	1.33	1.97	197
A4	2.25	1.00	2.25	56
A5	1.92	1.02	1.89	19
A6	2.00	1.00	2.00	160
A7	2.00	1.00	2.00	50
A8	3.69	1.80	2.05	49
A9	2.11	1.00	2.11	11
A10	3.00	1.00	3.00	30
A11	2.03	1.00	2.03	20
A12	2.00	1.00	2.00	30
A13	2.44	1.21	2.02	40
A14	2.51	1.40	1.79	36
A15	2.60	1.56	1.66	42
A16	2.81	1.67	1.69	42
A17	2.25	1.00	2.25	56
A18	2.11	1.00	2.11	42
A19	2.00	1.00	2.00	60
A20	2.35	1.31	1.79	54

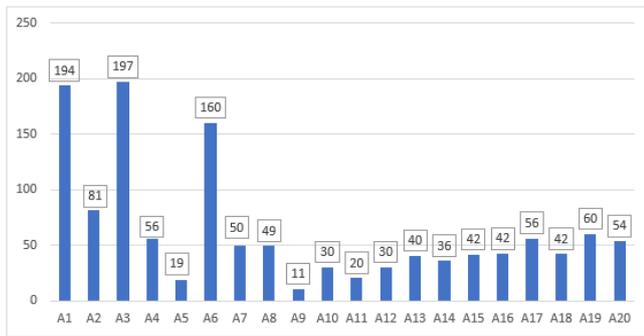


Fig. 14. Results of purchase order suggestion (SS*Z)

These data test results are used to determine the accuracy of the results and actual data. The author conducted an experiment 20 times with different input criteria and compared with the results of the original data that would be in the percentage of comparison for the feasibility of the system being the subject. Based on the results of system testing that has been done, it can be concluded that the forecasting system ordering the number of items purchased by PT. X with the feasibility of the program with the percentage difference in the average error is 0.5%.

V. CONCLUSION AND FUTURE WORK

Based on the author's review of the application of fuzzy Tsukamoto in the DSM for ordering items, a conclusion can be drawn. In implementing the FIS using the Tsukamoto method to determine the number of items purchased, there are 3 steps taken, namely fuzzification, inference, and defuzzification. The model developed has been made to predict the number of items purchased in pharmacy companies, so that it can run efficiently.

In the future, fuzzy variables used for input must be more than 2 variables, it will produce better results when variables are more complex.

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AUTHORS PROFILE



Guroh Kharisma Ramadhan is received the Bachelor of Information Technology in Computer Science in Bina Nusantara University, BINUS. He is currently pursuing Master of Computer Science in Bina Nusantara University, Jakarta, Indonesia. His research interests are focused in optimization techniques and decision support model for solving several cases of decision-making problem.



Ditdit Nugeraha Utama is a faculty member of Computer Science Department, BINUS Graduate Program – Master of Computer Science, Bina Nusantara University, Jakarta, Indonesia. He graduated from Mathematics and Informatics department of Doctoral Program in Göttingen University, Germany; where his doctoral-research conducted in environmental-informatics field specifically. His research interest is regarding decision support model for solving several cases of decision making problem.