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To cite this article: S L B Ginting *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **879** 012039

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The Application of Fuzzy Logic Method in the Debtors Eligibility Assessment System of Microfinance Institution

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Abstract. Decision-making processes in determining loan eligibility are often subjective which leads to imprecise credit predictions. Due to inaccurate inquiry on prospective customers done by field survey officers of Bank Perkreditan Rakyat (BPR) Bandung City, it has experienced credit complications such as bad credits. Therefore, this study aims to help decision-makers in determining creditworthiness and preventing bad credits from occurring. To realize this solution, the study uses the Fuzzy Logic method to calculate the creditworthiness of each prospective loaner based on the inquiries done in the field survey. Fuzzy Logic is known to be a “counting” methodology with varying words. In addition, it can implement human expertise into machine language with ease and adequately. Based on numerous testing performed, the results demonstrate a level of 90% in accuracy when inputting within the valid ranges of each fuzzy set and membership function. However, the level of accuracy is only based on the clarification result which is determined by a researcher and BPR director, not a general level of accuracy for other microfinance institutions. Nevertheless, the findings of this study prove the method has a high enough accuracy to support decision-makers in determining the loan eligibility of prospective loaners and through this application in the surveying process, survey workers can work more efficiently. Hence, in future has a higher chance of predicting bad credits from potential loaners.

Keywords: BPR (Microfinance), Decision_Making, Fuzzy_Logical_Method, Prospective_Loaners, Preventing_Bad_Credits

1. Introduction

According to the statistics from the Ministry of Cooperatives and Small and Medium Enterprises (SMEs), Ministry of Micro, Small & Medium Enterprises (MSME) contributed up to 60.34 percent of Gross Domestic Product (GDP). On the other hand, Indonesia Economic Census 2016 shows that 99.37 percent of the business units are Micro and Small Enterprises (MSEs). From this nominal increase, there is an institution which has an important role in overcoming poverty in Indonesia [1]. This institution is called the Microfinance Institution (MFI) which has the role to carry out microfinance services effectively [2,3]. With the number of business unit growing rapidly, individual businesses experience fundamental problems, such as limited funding. This problem is usually handled by MFIs who are the main figures in the development of microfinance and the provision of special services for capital [2,4]. Bank Perkreditan Rakyat (BPR) is an MFI in the form of a bank and, according to Bank Indonesia (BI) 2012, became an intermediary institution in microfinance that is focused on providing services to small businesses and rural communities [2,5]. The above description implies how important the role of MFI is to UMKM and that further research is needed in order to raise a case study from an MFI in the form



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of a bank, particularly in Bandung City. BPR Bandung City is currently facing several problems in providing credit services to MSEs. One obstacle faced is the quality of resources that are still inadequate both in managerial and operational technical levels [6]. Operational techniques that are still in the process of applying for loans are still using manual methods such as the use of pen and paper in the survey process for prospective new customers. This can cause inaccurate and ineffective customer data in determining creditworthiness. Therefore, a system is needed in order to help the classification process of loan eligibility with the help of a method that can process their classification. Hence the intent of this study is to form a system that can help survey officers in the process of determining the creditworthiness of loans with the use of the Fuzzy Logic Algorithm in classifying loan eligibility. Thus, more accurate and effective data can be produced.

The method applied in the construction of this system is called Fuzzy Tsukamoto. Tsukamoto's Fuzzy Method simulates human expertise and implements it in machine language and interprets unclear statements into more logical terms [7-9]. The method was chosen due to the problem with determining the feasibility of a loan and it is considered a classification problem that is full of obscurity. Therefore this method will define gray areas that are difficult to analyze and classify them into clusters that are easier to understand [8]. Input variables used in this algorithm are age, finance, loan nominal, and installments. After the officer has inputted the data, Fuzzy Tsukamoto will calculate the value of the creditworthiness based on the prospective customer's data. In the end, it will produce two final decisions, which are eligible or not eligible. With the help of these results, survey officers can complete each survey accurately and efficiently.

There have been numerous studies from different fields that possess similarities with this research. A. Setyono and S.N. Aeni, in their research, they adopted the Fuzzy Tsukamoto method to regulate the number of orders of goods to stock in a decision support system. The study shows that the Fuzzy Tsukamoto method can improve ordering accuracy by 20% compared to the previous method [10]. Moreover, an operation of Fuzzy Tsukamoto's inference system in the planning of palm oil crude production for a decision-making process was carried out by A.T. Bon with S.F. Utami. This application displays an increase in profit margins of palm oil production by 21% from the initial production [11]. Furthermore, M. Maryaningsih and Siswato utilize fuzzy logic in the scholarship acceptance decision-making system. In this application, the Fuzzy Tsukamoto method can simplify the process of determining scholarships based on specified criteria [7].

As demonstrated by the results of earlier studies described above, Fuzzy Logic can be considered as an effective and accurate method used in the process of decision making. Another advantage is that this method has a high level of flexibility since it is easy to adjust to the criteria that the compilers set. Therefore, the Tsukamoto Fuzzy method is the most suitable to be implemented in this case study.

2. Method

In 1965 Prof. Lotfi A. Adeh introduced the Fuzzy Logic as one of the many forms based on soft computing [12]. Fuzzy Logic consists of the basis of Fuzzy set theories and in this set of theory, the membership level takes a very important role in determining the existing elements on the set [12]. There are three main characteristics in reasoning with Fuzzy Logic and they are: membership value, membership level and membership function [7]. This method is able to map out the input and output fields using the if-then rule [11]. In the Fuzzy set, the membership value is around 0 to 1, the set is crisp and there are only two membership values, namely 0 and 1. In order to state whether x is a full member of a set, namely set A then it needs to have a membership value of $\mu_A[x] = 1$. This implies that x is a full member of set A , Fuzzy set has two attributes namely linguistic and numerical [12].

The membership function is represented by a curve that shows input into the membership value (degree of membership). There are several membership functions such as linear membership function as shown in Figures 1 and 2, triangle membership function in Figure 3 and trapezoid membership function as represented in Figure 4. All functions mentioned only have intervals between 0 and 1 [7]. Below are the graphical representations of the many membership functions.

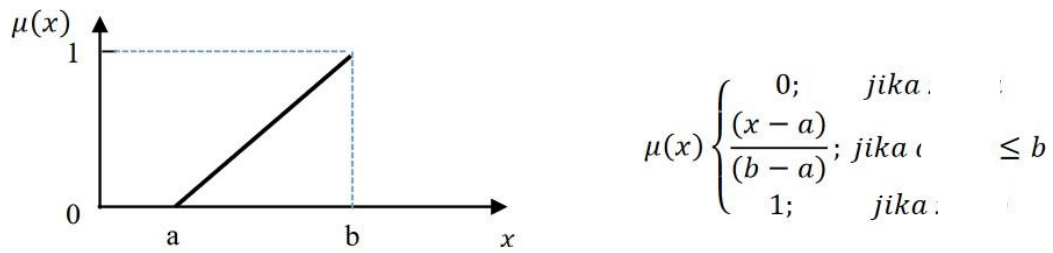


Figure 1. Portrayal of a linear rise by graphic representation

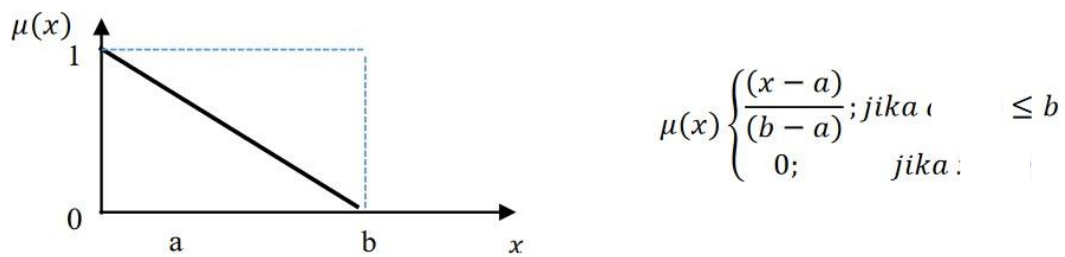


Figure 2. Portrayal of a linear fall by graphic representation

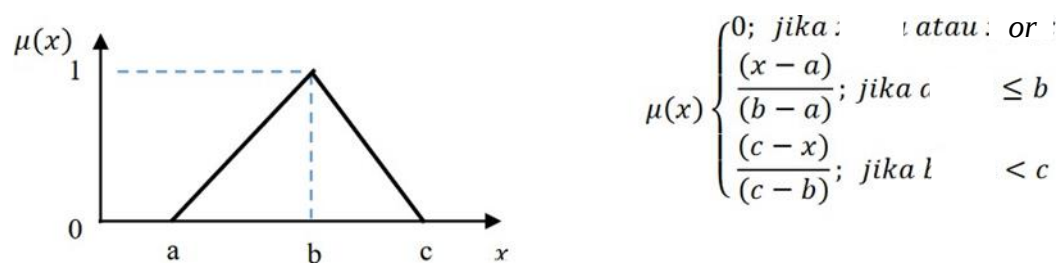


Figure 3. Portrayal of a triangle curve by graphic representation

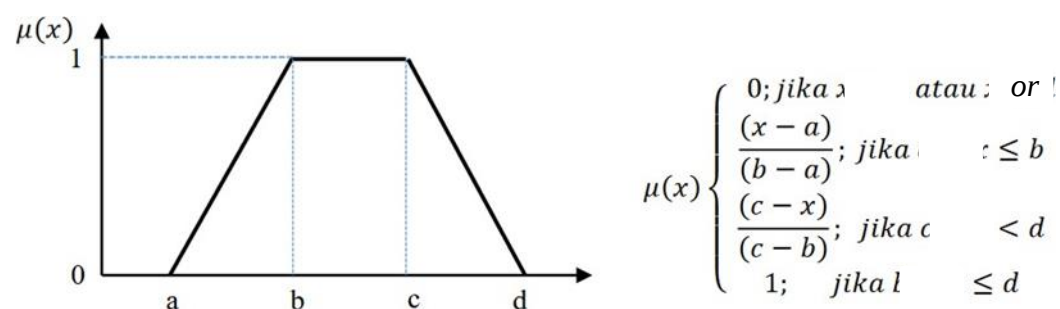


Figure 4. Portrayal of a trapezium curve by graphic representation

In Tsukamoto's method, the formation of rules, in general, is in the form of IF-THEN. Tsukamoto's Fuzzy model forms are as follows X, Y & Z are equal to the Fuzzy sets of A, B & C. To attain the α predicate of individual rule, the inference engine operates with the MINIMAL implication function. Therefore, the output results of the explicit inference (crisp output) are calculated by each α -predicate value. Defuzzification process uses the Center Average method [12-14].

$$Z = \frac{\sum a_i, z_i}{\sum a_i}$$

The database of credit loans received at BPR Bandung City in recent years was used in the development of this study. The data source holds about 500 data containing the number of loans, the range of loans and how credit is maintained until the payment due date. Additional data is used from the Dummy Database which is used to simulate more data in accordance with financial calculations performed from BPR Bandung City.

3. Results and Discussion

3.1. Implementation Calculation Using Fuzzy Logic

In implementing the Tsukamoto method there are three steps in determining the feasibility of a loan: defining variables, inference, and defuzzification.

1. Defining Fuzzy variables

The first stage is determining the membership value of the Fuzzy set by considering the minimum and maximum value of BPR Bandung City customers' current data. The other variables are age variable, financial variable, loan variable and installment variable which are modeled as follows.

- a. Age (x), consisting of 3 linguistics, namely young (UM), adult (UD) and elderly (UT). Therefore, the membership function can be formulated as follows:

$$\begin{aligned} \mu_{UM}(x) &= \begin{cases} 1 & ; x \leq 32 \\ \frac{35-x}{35-32} & ; 32 \leq x \leq 35 \\ 0 & ; x \geq 35 \end{cases} \\ \mu_{UD}(x) &= \begin{cases} 0 & ; x \leq 29 \text{ atau } x \geq 55 \\ \frac{x-29}{49-29} & ; 29 < x \leq 49 \\ \frac{55-x}{55-49} & ; 49 < x < 55 \end{cases} \\ \mu_{UT}(x) &= \begin{cases} 0 & ; x \leq 45 \\ \frac{x-45}{60-45} & ; 45 < x \leq 60 \\ 1 & ; x \geq 60 \end{cases} \end{aligned}$$

- b. Nominal finances (x), consisting of 3 linguistics, namely small (NKK), medium (NKM) and high (HCV). Then the membership function can be formulated as follows:

$$\begin{aligned} \mu_{NKK}(x) &= \begin{cases} 1 & ; x \leq 3500000 \\ \frac{4000000-x}{4000000-3500000} & ; 3500000 \leq x \leq 4000000 \\ 0 & ; x \geq 4000000 \end{cases} \\ \mu_{NKM}(x) &= \begin{cases} 0 & ; x \leq 3000000 \text{ atau } x \geq 14000000 \\ \frac{x-3000000}{12000000-3000000} & ; 3000000 < x \leq 12000000 \\ \frac{14000000-x}{14000000-12000000} & ; 12000000 < x < 14000000 \end{cases} \\ \mu_{NKT}(x) &= \begin{cases} 0 & ; x \leq 10000000 \\ \frac{x-10000000}{30000000-10000000} & ; 10000000 < x \leq 30000000 \\ 1 & ; x \geq 30000 \end{cases} \end{aligned}$$

- c. Nominal loans (x), consisting of 3 linguistics, namely small (NPK), medium (NPM) and high (NPT). Then the membership function can be formulated as follows:

$$\mu_{\text{NPK}}(x) = \begin{cases} 1 & ; x \leq 9500000 \\ \frac{10500000-x}{10500000-9500000} & ; 9500000 \leq x \leq 10500000 \\ 0 & ; x \geq 10500000 \end{cases}$$

$$\mu_{\text{NPM}}(x) = \begin{cases} 0 & ; x < 8000000 \\ \frac{x-8000000}{20000000-8000000} & ; 8000000 < x \leq 20000000 \\ \frac{21000000-x}{21000000-20000000} & ; 20000000 < x < 21000000 \end{cases}$$

$$\mu_{\text{NPT}}(x) = \begin{cases} 0 & ; x \leq 18000000 \\ \frac{x-18000000}{30000000-18000000} & ; 18000000 < x \leq 30000000 \\ \frac{40000000-x}{40000000-30000000} & ; 30000000 < x < 40000000 \end{cases}$$

- d. Installment term (x), consists of 2 linguistics, namely short (APEN) and long (APAN). Then the membership function can be formulated as follows:

$$\mu_{\text{APEN}}(x) = \begin{cases} 1 & ; x \leq 18 \\ \frac{20-x}{20-18} & ; 18 \leq x \leq 20 \\ 0 & ; x \geq 20 \end{cases}$$

$$\mu_{\text{APAN}}(x) = \begin{cases} 0 & ; x \leq 12 \\ \frac{x-12}{30-12} & ; 12 < x \leq 30 \\ \frac{32-x}{32-30} & ; 30 < x < 32 \end{cases}$$

2. Inference

The next step uses a rule base that is based on analyzed data from BPR Bandung customers. This Fuzzy preference is a collection of if-then rules and can be described as follows in Table 1. This table shows all the possible outcomes from all 4 variable inputs.

Table 1. Snippet of table rules base

No.	Age (Young/Adult/ Elderly)	Nominal Finance (Small/Moderate/ High)	Nominal Loans (Small/Moderate/ High)	Instalment Term (Short/Long)	Eligibility
1	Young	Small	Small	Short	Not eligible
2	Young	Small	Small	Long	eligible
3	Young	Small	Moderate	Short	Not eligible
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
52	Elderly	Moderate	Small	Long	Eligible

No.	Age (Young/Adult/ Elderly)	Nominal Finance (Small/Moderate/ High)	Nominal Loans (Small/Moderate/ High)	Instalment Term (Short/Long)	Eligibility
53	Elderly	Moderate	Moderate	Short	Eligible
54	Elderly	Moderate	Moderate	Long	Eligible

The results obtained from the previous calculations will then produce one or more outcomes based on the similarity in the Rules Base. Thus, next is to calculate α -predicate, z , and $(\alpha\text{-predicate} * z)$ with the formula:

$$\alpha\text{-predicate} = \mu_{\text{Age}} \cap \mu_{\text{Finance}} \cap \mu_{\text{Loan}} \cap \mu_{\text{Instalments}}$$

$$z = z_{\max} - \alpha\text{predicate}(z_{\max} - z_{\min})$$

3. Defuzzification

The final step of the method is a centralized average defuzzification to determine the crisp output using the formula:

$$Z = \frac{\sum \alpha\text{predikat} * z}{\sum \alpha\text{predikat}}$$

3.2. Test Result

The following Table 2, displays the testing results of the calculation done by the Fuzzy Tsukamoto method that has been implemented with an Android-based application compared to the BPR formulation.

Table 2. Tsukamoto Fuzzy method test results table for comparison

No	Variabel input				Result	
	Age	Finance (Rp)	Loan (Rp)	Instalments (month)	BPR Formulation	Fuzzy Tsukamoto
1	21	15,206,252	17,867,803	16	Eligible	Eligible
2	48	4,795,631	27,629,010	21	Not Eligible	Not Eligible
3	58	20,421,406	12,218,591	13	Eligible	Eligible
4	37	35,751,064	28,022,727	19	Eligible	Eligible
5	49	17,658,022	26,204,057	31	Eligible	Eligible
6	27	45,477,700	15,363,582	12	Eligible	Eligible
7	43	3,936,057	28,001,872	23	Not Eligible	Eligible
8	60	6,853,595	11,044,101	20	Eligible	Eligible
9	55	19,068,425	11,862,365	27	Eligible	Eligible
10	56	3,000,000	9,000,000	22	Eligible	Eligible

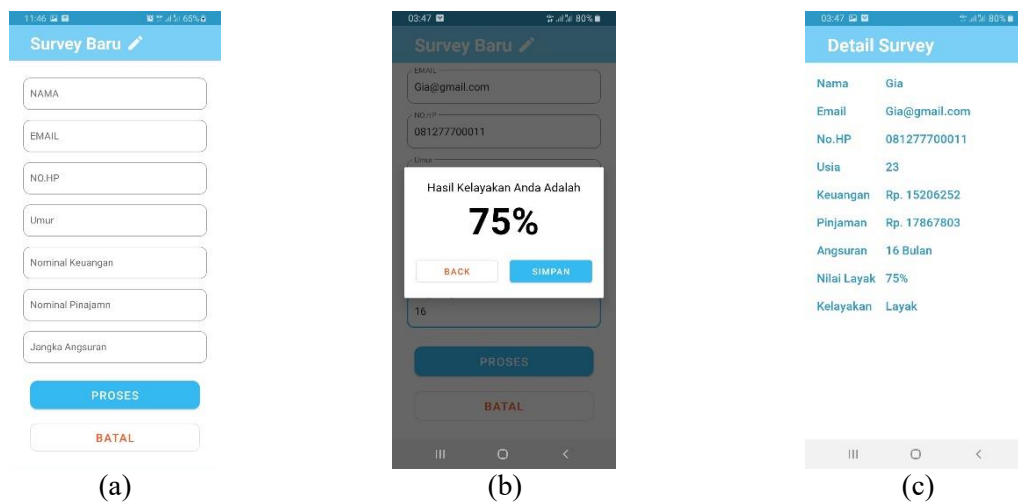


Figure 5. (a) Display of survey menu (b) Display of the eligibility results menu (c) Display of the customer data menu

In figure 5(a), it shows the many variable inputs that will be used in order to calculate the eligibility score of a potential loaner through the Fuzzy method. Figure 5(b) shows the results of the calculated input based on Figure 5(a) and for this example, it shows a 75% eligibility for the loaner based on the data shown in Figure 5(c). Figure 5(c) shows the complete inputted data from the menu shown in Figure 5(a).

Based on the results obtained in testing the Fuzzy Tsukamoto method as seen in Table 2, it can be concluded that the application has 1 difference in comparing the results of manual calculations with the application. This shows the application has a success rate of 90%. The results of the final decision are influenced by input variables determined in the beginning [12-14]. Based on the testing that has been done, it can be stated that to get maximum results, the fuzzy set and rules base need to be validated by appropriate experts so that the data is more accurate.

4. Conclusion

After analyzing the application of Tsukamoto's Fuzzy Logic Algorithm in determining the feasibility of a loan implemented as an android-based application, an accuracy of 90% was obtained. Hence, Fuzzy Tsukamoto's method succeeded in serving an accurate eligibility prediction on determining borrowers' eligibility. Through using this application in the surveying process, survey workers can work quickly and efficiently.

Acknowledgement

We would like to thank Mr. Firman and Mr. Sidiq as the President Directors of Kredit Melati at BPR Bandung City, who granted permission to carry out the research within their company and assist us with the data collection process from the start until the application was complete. We would also like to thank all of the company staff for facilitating this research.

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