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A New Method to Analyze Bank Performance Level in Indonesia Using Fuzzy Model

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Abstract

Banking industry has a vital role in improving the economic condition of a country, hence the measurement of bank performance level is very important for every country. This paper proposes a new method of analyzing the bank performance level in Indonesia. The method uses fuzzy model of zero-order Takagi-Sugeno-Kang (TSK) with singular value decomposition (SVD) to measure the financial performance of conventional banks in Indonesia based on risk profile, good corporate governance, earning, and capital (RGEC) variables. In fuzzy model, constructing fuzzy rules is very important to increase the accuracy of the model. In this research, the training data is used to build fuzzy rules. The parameters of consequents of the rules are determined by singular value decomposition method. This paper also compares the result of analyzing bank performance level using fuzzy models of Mamdani, zero-order TSK, and zero-order TSK with SVD. The accuracy of fuzzy models of Mamdani, zero-order TSK and zero-order TSK with SVD for training data are 87,356%, 96,16%, and 99,23%, respectively.

While the accuracy for testing data of those models are 99,919%, 100% and 100%, respectively. It means that fuzzy model of zero-order TSK with SVD gives better accuracy than other methods for analyzing bank performance level in Indonesia.

Keywords: bank performance, RGEC, Mamdani fuzzy model, zero-order TSK fuzzy model, singular value decomposition

1. Introduction

Banking system has become an integral part for operating economic activities in every country [1]. It has a vital role in improving the economic condition of a country because most of the life sectors related to finances need the banking service. Bank is a financial intermediary institution in carrying out its business activities by relying on public funds and trust [2]. Public confidence in the bank will grow when the bank has a good level of performance. On this account, it is essential to know the performance level of banks.

Many researchers have studied the method to analyze bank performance level. The study on bank performance level was conducted using logit analysis to enhance business failure predictability [3].The prediction of financial bankruptcy risk was established by using the Altman model and back-propagation neural networks [4]. Then, CAMEL and regression methods were used to determine the financial performance of commercial bank in Kenya [5]. Moreover, squared correlation coefficient method was applied to analyze five commercial banks in Bangladesh [6].

In [7], study on the variables having the significant effect on bank performance was done. Afterwards, researchers used student's t-test to analyze bank performance [8], [9]. Then, regression analysis was used to test the relationship among the profitability variables (ROA, ROD, ROE) [10]. In [11], CAMEL (Liquidity, Efficiency, Profitability, Capital Adequacy and Assets Quality) method and AHP were applied to evaluate the performance of commercial banks in Nepal. The comparison of the financial performance between conventional and Islamic banking in United Arab Emirates was done by using several factors of banks ratio with Z-Score [12].

The Cox Proportional Hazard Model was used to assess the usefulness of traditional financial ratios and market variables as the predictors of the probability of business failure in Taiwan [13]. Then, ratio analysis method was used to measure the company's performance. The data used for analysis was extracted from the financial statements of Zenith Bank Plc within the range of twelve years (2000 -2011) [14].Following this, RGEC method with Man-Whitney was applied to compare 15 conventional banks to Islamic banks [15]. The performance of PT. Bank Rakyat Indonesia was analyzed by RGEC method [16].

Several scientists applied fuzzy model to analyze banks performance level. The combination of Altman's Z-score and ANFIS methods based on time series data was used to predict bankruptcy [17]. Then, the determination of financial failure of the Egyptian commercial banks was done by fuzzy logic with Matlab and GUI using the bank financial performance indicators i.e. capital adequacy, asset quality, liquidity, and earnings [18].Then, the DRSA (dominance-based rough set approach) method with neural network was applied to analyze the financial condition prediction of bank in Taiwan [19].

The comparison of capability of fuzzy neural network TSK, ANFIS, fuzzy group method of data handling (FGMDH), ARMA, logit model, and probit model to analyze banks bankruptcy risk of European banks was performed. The results showed that the fuzzy model gave better accuracy than crisp methods (ARMA, logit-model and probit-model) [20]. Moreover, the analysis of performance of 107 banks in Indonesia by using CAMEL method was conducted by using Mamdani fuzzy logic [21]. The research to classify the performances of banks in Indonesia using RGEC method and zero-order TSK fuzzy model was done [22].

The undertaken studies increasingly emphasized that the performance level of a company, especially banks are very pivotal to know. Factors used to examine the soundness of banks in various countries are almost similar. In Indonesia, a method used to assess the performance of banks is often referred to as RGEC. Fuzzy system can be interpreted as a complete linguistic description about the processes which can be combined into a model [23]. Fuzzy systems are able to display based on qualitative and quantitative data.

The inference methods often used in a fuzzy system are Mamdani and Takagi-Sugeno-Kang (TSK) methods. In this paper, we build fuzzy model of zero-order TSK by using singular value decomposition (SVD) and apply it to assess the performance of banks in Indonesia.

2. Risk Profile, Good Corporate Governance, Earning, and Capital (RGEC)

There are many techniques and methods for banks financial state analysis and determination of proper bank rating i.e. CAMEL and CAMELS, Web Money, Moody’s, and S&P. The method used to assess the performance of banks in Indonesia is RGEC method. This method contains the assessment of general bank performance level with the risk approach including the assessment of four factors. They are Risk Profile, Good Corporate Governance, Earning, and Capital [24]. The RGEC factor in this research is only limited by the risk profile, earnings, and capital. Risk profile factor uses two ratio indicators i.e. Non-Performing Loan (NPL) and Loan to Deposit Ratio (LDR). The earnings factor uses the ratio of Return on Assets (ROA), Return on Equity (ROE), Net Interest Margin (NIM). Capital Adequacy Ratio (CAR) is used to analyze the Capital factor. The determination of NPL and LDR ranking can be seen on the Table 1.

Table 1: Matrix of Ranking Determination Criteria of NPL and LDR [25], [26]

Ranking	Information	NPL Criteria	LDR Criteria
1	Very good	$\mathrm{NPL} < 2\%$	$\mathrm{LDR} \leq 75\%$
2	Good	$2\% \leq \mathrm{NPL} < 3{,}5\%$	$75\% < \mathrm{LDR} \leq 85\%$
3	Good enough	$3{,}5\% \leq \mathrm{NPL} < 5\%$	$85\% < \mathrm{LDR} \leq 100\%$
4	Less than good	$5\% \leq \mathrm{NPL} \leq 8\%$	$100\% < \mathrm{LDR} \leq 120\%$
5	Not good	$\mathrm{NPL} > 8\%$	$\mathrm{LDR} > 120\%$

The matrix of ranking determination criteria of Return on Assets (ROA) ratio, Return on Equity (ROE) ratio, and Net Interest Margin (NIM) is presented in Table 2.

Table 2: Matrix of Ranking Determination Criteria of ROA and NIM [26], [27]

Ranking	Information	ROA Criteria	ROE Criteria	NIM Criteria
1	Very good	$\mathrm{ROA} > 1{,}5\%$	$\mathrm{ROE} > 20\%$	$\mathrm{NIM} > 5\%$
2	Good	$1{,}25\% < \mathrm{ROA} \leq 1{,}5\%$	$12{,}51\% \leq \mathrm{ROE} \leq 20\%$	$2.01\% \leq \mathrm{NIM} \leq 5\%$
3	Good enough	$0{,}5\% < \mathrm{ROA} \leq 1{,}25\%$	$5{,}01\% \leq \mathrm{ROE} \leq 12{,}5\%$	$1.51\% \leq \mathrm{NIM} \leq 2\%$
4	Less than good	$0\% < \mathrm{ROA} \leq 0{,}5\%$	$0\% \leq \mathrm{ROE} \leq 5\%$	$0\% \leq \mathrm{NIM} \leq 1.49\%$
5	Not good	$\mathrm{ROA} \leq 0\%$	$\mathrm{ROE} < 0\%$	$\mathrm{NIM} < 0\%$

Standard ratio Capital Adequacy Ratio (CAR) can be seen in Table 3.

Table 3: Matrix of Ranking Determination Criteria of Capitalization [26]

Ranking	Information	Criteria
1	Very good	$\mathrm{KPMM} > 12\%$
2	Good	$9\% < \mathrm{KPMM} \leq 12\%$
3	Good enough	$8\% < \mathrm{KPMM} \leq 9\%$
4	Less than good	$6\% < \mathrm{KPMM} \leq 8\%$
5	Not good	$\mathrm{KPMM} \leq 6\%$

3. Fuzzy Systems

Fuzzy system is a series of processes to build a model based on fuzzy logic. The steps of constructing fuzzy system consist of fuzzification, building rules, fuzzy inferencing and defuzzification. Fuzzification is the first step of fuzzy system which transformed the crisp input variable into a fuzzy set. Then the fuzzy rules were built by training data or expert judgment. Fuzzy inference is a function transforming fuzzy rule base and fuzzy inputs to fuzzy set as a output.The last step in constructing fuzzy system is called defuzzification converting the fuzzy set into a real number. The process to construct fuzzy systems is shown in Figure 1. Fuzzy inference that is usually used are Tsukamoto, Mamdani, and Takagi-Sugeno-Kang (TSK) methods [28]. There are two types of TSK method, i.e. zero-order TSK and one-order TSK.

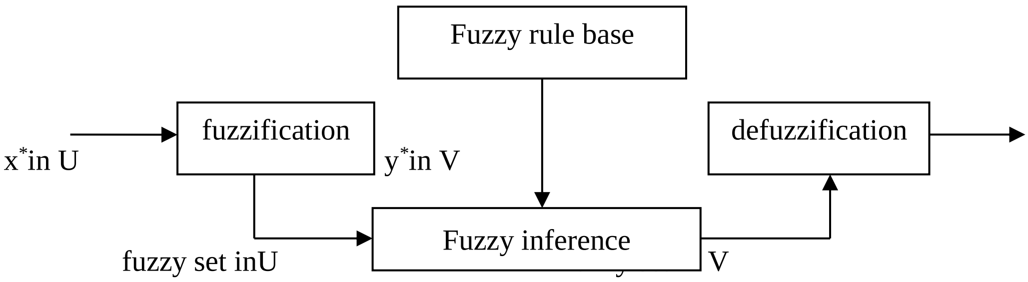

Figure 1: Construction of fuzzy systems [23]

4. Singular Value Decomposition of Matrix

In this section, we will introduce singular value decomposition of matrix and its properties referred from [29]. Any *m* x *n* matrix ***A*** can be expressed as

$$A = USV^T \tag{1}$$

Where ***U*** and ***V*** are orthogonal matrices of dimensions *m* x *m*, *n* x *n* respectively and ***S*** is *m* x *n* matrix whose entries are 0 except s_{ii} = σ_i $i = 1, 2, ..., r$ with $\sigma_1 \geq \sigma_2 \geq ... \geq \sigma_r \geq 0$, $r \leq \min(m,n)$. Equation (1) is called a singular value decomposition (*SVD*) of ***A*** and the numbers σ_i are called singular values of ***A***. If U_i , V_i are columns of ***U*** and ***V*** respectively, then equation (1) can be written as

$$A = \sum_{i=1}^{r} \sigma_i U_i V_i^T \tag{2}$$

The *SVD* can be used to solve the system $Ax = d$. If *A* is *n* x *n* invertible matrix, then *r* = *n* and all $\sigma_i > 0$. Hence $x = A^{-1}d = \sum_{i=1}^{n} \sigma_i^{-1} < d, U_i > V_i$ where $<,>$ is standard inner product in R^n . If ***A*** is singular matrix and of arbitrary dimension, then solution of $Ax = d$ is

$$x^+ = \sum_{i=1}^{r} \sigma_i^{-1} < d, U_i > V_i \ . \tag{3}$$

Furthermore, $\min\left\{ \| Ax - d \| : x \in F^n \right\} = \| Ax^+ - d \|$. The *SVD* can be used to analysis sensitivity of the system.

Let $\| A \|_F^2 = \sum_{i,j} a_{ij}^2$ be the Frobenius norm of ***A***. Because *U* and ***V*** are orthogonal matrices, then $\| U_i \| = 1$ and $\| V_i \| = 1$. Hence $\| A \|_F^2 = \left\| \sum_{i=1}^{r} \sigma_i U_i V_i^T \right\|_F^2 = \sum_{i=1}^{r} \sigma_i^2$.

Let $A = USV^T$ be *SVD* of *A*. For given $p \leq r$, the optimal rank *p* approximation of *A* is given by $A_p = \sum_{i=1}^{p} \sigma_i U_i V_i^T$.

Then $\| A - A_p \|_F^2 = \left\| \sum_{i=1}^{r} \sigma_i U_i V_i^T - \sum_{i=1}^{p} \sigma_i U_i V_i^T \right\|_F^2 = \left\| \sum_{i=p+1}^{r} \sigma_i U_i V_i^T \right\| = \sum_{i=p+1}^{r} \sigma_i^2$. This means that A_p is the best rank *p* approximation of ***A*** and the approximation error depends only on the summation of the square of the rest singular values.

5. The Construction of Zero-Order TSK Fuzzy Model Using SVD

In this section, we propose an application of SVD to construct zero-order TSK fuzzy model. The steps to construct the fuzzy model using singular value decomposition are as follows:

a. Fuzzification

Fuzzification process will transform the crisp set into fuzzy set [23]. In this paper, we use singleton fuzzifier.

b. Construction of fuzzy rules

The general form of fuzzy rule of zero order TSK is as follows [30]

$$If\ (x_1\ is\ A_1) \circ (x_2\ is\ A_2) \circ \ldots \circ (x_i is\ A_i)\ then\ y_i = b_i \tag{4}$$

where,

x_i : input variable for-i, i=1,2,..,n.

A_i : fuzzys et for-i at $x_i$variable as antecedent

b_i : constant of consequent to be determined

$\circ$: fuzzy operator

c. Defuzzification

Defuzzification process is aimed to get the crisp value at the output. The process of defuzzification in this research uses the method of weight average with formula [23]:

$$\boldsymbol{y} = \frac{\sum_{i=1}^{L} y_i(\mu_{i1}(x_1)\mu_{i2}(x_2)\ldots\mu_{in}(x_n))}{\sum_{i=1}^{L} \mu_{i1}(x_1)\mu_{i2}(x_2)\ldots\mu_{in}(x_n)} \tag{5}$$

where:

y_i : consequent of the ith rules, $i = 1, 2, \ldots, L$.

$\mu_{ij}(x_j)$: degree of membership function of$x_j$variable in the ith rule. $j = 1, 2, \ldots, n$.

d. Computation $\boldsymbol{b_i}$ as constant of consequent using singular value decomposition method

The equation (5) can be stated as:

$$\boldsymbol{y} = \sum_{i=1}^{L} \boldsymbol{w_i y_i} \tag{6}$$

where

$$\boldsymbol{w_i} = \frac{\mu_{i1}(x_1)\mu_{i2}(x_2)\ldots\mu_{in}(x_n)}{\sum_{i=1}^{L} \mu_{i1}(x_1)\mu_{i2}(x_2)\ldots\mu_{in}(x_n)}. \tag{7}$$

Based on [31], the formula set up a model which minimizes the objective function $\boldsymbol{J}$ with

$$\boldsymbol{J} = \sum_{k=1}^{N} \left(\boldsymbol{d(i)} - \boldsymbol{y(i)}\right)^{2} = (\boldsymbol{d} - \boldsymbol{Xb})^{T}(\boldsymbol{d} - \boldsymbol{Xb}) \tag{8}$$

$$\boldsymbol{d} = [\boldsymbol{d}(\mathbf{1})\boldsymbol{d}(\mathbf{2}) \dots \boldsymbol{d}(\boldsymbol{N})]^{\boldsymbol{T}} \tag{9}$$

where

$\boldsymbol{d}(\boldsymbol{i})$:the real output for all *i*-data pairs

$\boldsymbol{y}(\boldsymbol{i})$:the zero order TSK model output for all *i*-data pairs.

$\boldsymbol{X}$:the matrix with size $\boldsymbol{N} \times \boldsymbol{L}$

$\boldsymbol{N}$:the number of data

$\boldsymbol{L}$:the number of formed fuzzy rules,

$\boldsymbol{b} = [\boldsymbol{b}_{\mathbf{10}}\boldsymbol{b}_{\mathbf{11}} \dots \boldsymbol{b}_{\mathbf{1}\boldsymbol{n}} \dots \boldsymbol{b}_{\boldsymbol{L}\mathbf{0}}\boldsymbol{b}_{\boldsymbol{L}\mathbf{1}} \dots \boldsymbol{b}_{\boldsymbol{L}\boldsymbol{n}}]^{\boldsymbol{T}}$ is the matrix with size $\boldsymbol{L} \times \mathbf{1}$.

The equation (8) can achieve a minimum if $\boldsymbol{d} - \boldsymbol{X}\boldsymbol{b} = \mathbf{0}$ or $\boldsymbol{d} = \boldsymbol{X}\boldsymbol{b}$ with

$$\boldsymbol{X} = \begin{bmatrix} \boldsymbol{w}_{\mathbf{1}}(\mathbf{1}) & \boldsymbol{w}_{\mathbf{2}}(\mathbf{1}) & \cdots & \boldsymbol{w}_{\boldsymbol{L}}(\mathbf{1}) \\ \boldsymbol{w}_{\mathbf{1}}(\mathbf{2}) & \boldsymbol{w}_{\mathbf{2}}(\mathbf{2}) & \cdots & \boldsymbol{w}_{\boldsymbol{L}}(\mathbf{2}) \\ \vdots & \vdots & \vdots & \vdots \\ \boldsymbol{w}_{\mathbf{1}}(\boldsymbol{N}) & \boldsymbol{w}_{\mathbf{2}}(\boldsymbol{N}) & \cdots & \boldsymbol{w}_{\boldsymbol{L}}(\boldsymbol{N}) \end{bmatrix} \tag{10}$$

where $\boldsymbol{w}_{\boldsymbol{j}}(\boldsymbol{i})$: the value of (7) for data *i*, $\boldsymbol{i} = \mathbf{1}, \mathbf{2}, \dots, \boldsymbol{N}$, $\boldsymbol{j} = \mathbf{1}, \mathbf{2}, \dots, \boldsymbol{L}$

Then, the solution of $\boldsymbol{d} = \boldsymbol{X}\boldsymbol{b}$ can be solved by using singular value decomposition of matrix $\boldsymbol{X}$ as (1), i.e. $\boldsymbol{X} = \boldsymbol{U}\boldsymbol{S}\boldsymbol{V}^{\boldsymbol{T}}$, where $\boldsymbol{U}$ and $\boldsymbol{V}$ are unitary matrix and $\boldsymbol{S}$ is matrix $\boldsymbol{N} \times \boldsymbol{L}$ in which all entries on the diagonal are singular values where zero beyond the diagonal. The parameter $\boldsymbol{b}$ can be determined by formula (3), i.e.

$$\widehat{\boldsymbol{b}} = \sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{r}} \boldsymbol{\sigma}_{\boldsymbol{i}}^{-\mathbf{1}} < \boldsymbol{d}, \boldsymbol{u}_{\boldsymbol{i}} > \boldsymbol{v}_{\boldsymbol{i}} = \sum_{\boldsymbol{i}=\boldsymbol{i}}^{\boldsymbol{r}} \frac{\boldsymbol{u}_{\boldsymbol{i}}^{\boldsymbol{T}}\boldsymbol{d}}{\boldsymbol{\sigma}_{\boldsymbol{i}}} \boldsymbol{v}_{\boldsymbol{i}} \tag{11}$$

$$U = [u_1, \dots, u_N], \text{and} V = [v_1, \dots, v_{(n+1)L}] \tag{12}$$

where r is the number of nonzero singular values.

6. The Application of Purposed Method to Analyze the Bank Performance

The data is obtained from Bank of Indonesia and the website of Financial Service Authority. There are 109 banks used in this research. Those names of banks are then given a code of 1, 2, 3,…,109 as the substitute of the names of the researched banks. This research is conducted for three years (2011-2013) so that there are 327 banks' data. The steps of the research are shown by Figure 2 as follows:

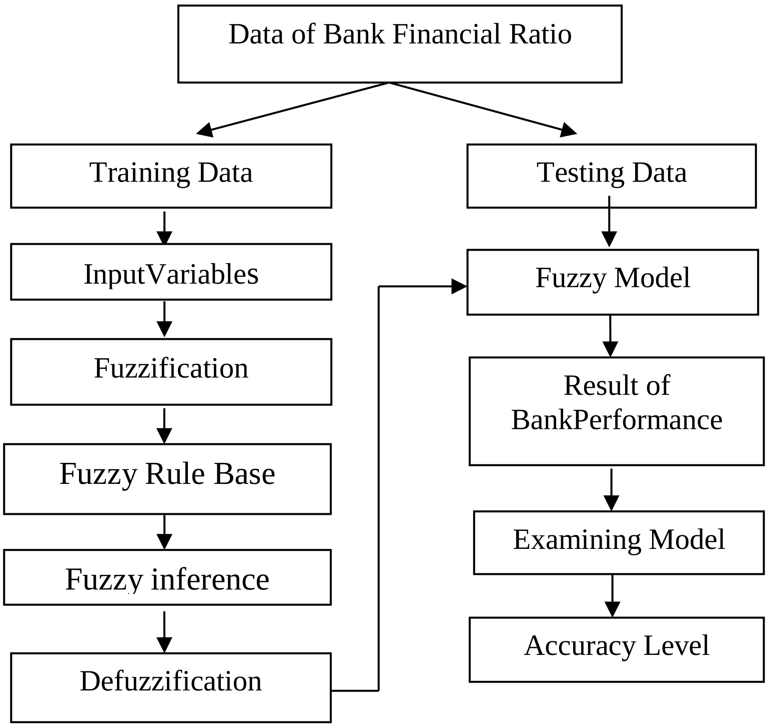

Figure 2: Steps of Analyzing Banks Performance Level

The first step is to determine the health of each banks surveyed using RGEC method. Then, we build a fuzzy system with the following steps:

A. Determining fuzzification

We define the universal set on each input and output. The interval of universal set covers the entire value of all the data used. Based on the data, the universal set of the input variables are defined as follows:

$U_{NPL} = [0, 13]$, $U_{LDR} = [0, 621$, $U_{ROA} = [-2, 8]$, $U_{ROE} = [-20, 144]$, $U_{NIM} = [-2, 21]$, and $U_{CAR} = [0, 182]$. The universal set on the output is defined as $U_{Output} = [0, 31]$. Furthermore, in each input variable, we construct five fuzzy sets using shoulder curve membership function. Shoulder curve is a combination of trapezoidal and triangular membership functions.

The fuzzy sets defined on the NPL ratio and LDR ratio are represented by the following membership functions:

$$\mu_{NPL_{VG}}(x) = \begin{cases} 1 & ; 0 \le x \le 1,5 \\ -x + 2,5 & ; 1,5 \le x \le 2,5 \\ 0 & ; x \ge 2,5 \end{cases}$$

$$\mu_{NPL_G}(x) = \begin{cases} 1 & ; x \le 1,5 \text{ or } x \ge 4,5 \\ x - 1,5 & ; 1,5 \le x \le 2,5 \\ \frac{4,5-x}{2} & ; 2,5 \le x \le 4,5 \end{cases}$$

$$\mu_{NPL_{GE}}(x) = \begin{cases} 0 & ; x \le 2,5 \text{ or } x \ge 5,5 \\ \frac{x-2,5}{2} & ; 2,5 \le x \le 4,5 \\ 5,5 - x & ; 4,5 \le x \le 5,5 \end{cases}$$

$$\mu_{NPL_{LG}}(x) = \begin{cases} 0 & ; x \le 4,5 \text{ or } x \ge 10,5 \\ x - 4,5 & ; 4,5 \le x \le 5,5 \\ \frac{10,5-x}{5} & ; 5,5 \le x \le 10,5 \end{cases}$$

$$\mu_{NPL_{NG}} = \begin{cases} 0 & ; x \le 5,5 \\ \frac{x-5,5}{5} & ; 5,5 \le x \le 10,5 \\ 1 & ; 10,5 \le x \le 13 \end{cases}$$

$$\mu_{LDR_{VG}}(x) = \begin{cases} 1 & ; 0 \le x \le 70 \\ \frac{80-x}{10} & ; 70 \le x \le 80 \\ 0 & ; x \ge 80 \end{cases}$$

$$\mu_{LDR_G}(x) = \begin{cases} 0 & ; x \le 70 \text{ or } x \ge 90 \\ \frac{x-70}{10} & ; 70 \le x \le 80 \\ \frac{90-x}{10} & ; 80 \le x \le 90 \end{cases}$$

$$\mu_{LDR_{GE}}(x) = \begin{cases} 0 & ; x \le 80 \text{ or } x \ge 110 \\ \frac{x-80}{10} & ; 80 \le x \le 90 \\ \frac{110-x}{20} & ; 90 \le x \le 110 \end{cases}$$

$$\mu_{LDR_{LG}}(x) = \begin{cases} 0 & ; x \le 90 \text{ or } x \ge 130 \\ \frac{x-90}{20} & ; 90 \le x \le 110 \\ \frac{130-x}{20} & ; 110 \le x \le 130 \end{cases}$$

$$\mu_{LDR_{NG}}(x) = \begin{cases} 0 & ; x \le 110 \\ \frac{x-110}{20} & ; 110 \le x \le 130 \\ 1 & ; 130 \le x \le 621 \end{cases}$$

The graphics of fuzzy sets on the input variable of NPL ratio and LDR ratio can be seen on the Figure 3 and Figure 4.

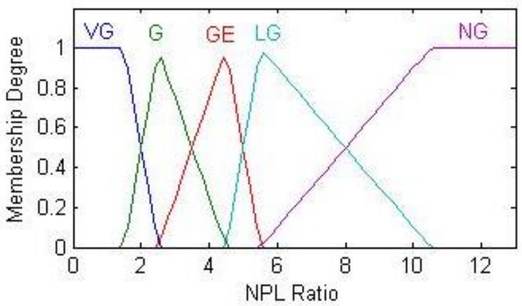

Figure 3: Fuzzy set in NPL variable

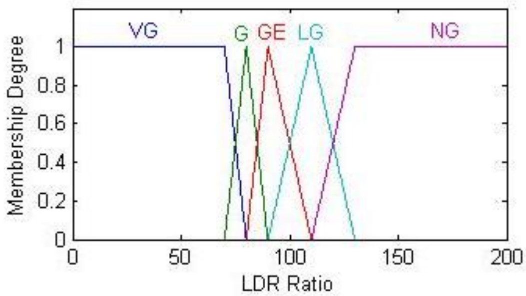

Figure 4: Fuzzy set in LDR variable

The fuzzy sets defined on the ROA ratio and ROE ratio are represented by the following membership functions:

$$\mu_{\mathbf{ROA}_{VG}} = \begin{cases} \mathbf{0} & ;\mathbf{x \leq 1,4} \\ \dfrac{\mathbf{x-1,4}}{\mathbf{0,2}} & ;\mathbf{1,4 \leq x \leq 1,6} \\ \mathbf{0} & ;\mathbf{1,6 \leq x \leq 8} \end{cases}$$

$$\mu_{\mathbf{ROA}_G}(\mathbf{x}) = \begin{cases} \mathbf{0} & ;\mathbf{x \leq 1,1 \text{ or } x \geq 1,6} \\ \dfrac{\mathbf{x-1,1}}{\mathbf{0,3}} & ;\mathbf{1,1 \leq x \leq 1,4} \\ \dfrac{\mathbf{1,6-x}}{\mathbf{0,2}} & ;\mathbf{1,4 \leq x \leq 1,6} \end{cases}$$

$$\mu_{\mathbf{ROA}_{GE}}(\mathbf{x}) = \begin{cases} \mathbf{0} & ;\mathbf{x \leq -0,1 \text{ or } x \geq 1,4} \\ \frac{\mathbf{x+0,1}}{\mathbf{1,2}} & ;\mathbf{-0,1 \leq x \leq 1,1} \\ \frac{\mathbf{1,4-x}}{\mathbf{0,3}} & ;\mathbf{1,1 \leq x \leq 1,4} \end{cases}$$

$$\mu_{\mathbf{ROA}_{LG}}(\mathbf{x}) = \begin{cases} \mathbf{0} & ;\mathbf{x \leq -0,2 \text{ or } x \geq 1,1} \\ \frac{\mathbf{x+0,2}}{\mathbf{0,1}} & ;\mathbf{-0,2 \leq x \leq -0,1} \\ \frac{\mathbf{1,1-x}}{\mathbf{1,2}} & ;\mathbf{-0,1 \leq x \leq 1,1} \end{cases}$$

$$\mu_{\mu_{\mathbf{ROA}_{NG}}}(\mathbf{x}) = \begin{cases} \mathbf{1} & ;\mathbf{-2 \leq x \leq -0,2} \\ \frac{\mathbf{-x-0,1}}{\mathbf{0,1}} & ;\mathbf{-0,2 \leq x \leq -0,1} \\ \mathbf{0} & ;\mathbf{x \geq -0,1} \end{cases}$$

$$\mu_{\text{ROE}_{VG}}(\text{x}) = \begin{cases} 0 & ;\text{x} \leq 17{,}5 \\ \dfrac{\text{x} - 17{,}5}{5} & ;17{,}5 \leq \text{x} \leq 22{,}5 \\ 1 & ;22{,}5 \leq \text{x} \leq 143 \end{cases}$$

$$\mu_{\text{ROE}_G}(\text{x}) = \begin{cases} 0 & ;\text{x} \leq 7{,}5 \text{ or } \text{x} \geq 22{,}5 \\ \frac{\text{x}-7{,}5}{10} & ;7{,}5 \leq \text{x} \leq 17{,}5 \\ \frac{22{,}5-\text{x}}{5} & ;17{,}5 \leq \text{x} \leq 22{,}5 \end{cases}$$

$$\text{M}_{\text{ROE}_{GE}}(\text{x}) = \begin{cases} 0 & ;\text{x} \leq 2{,}5 \text{ or } \text{x} \geq 17{,}5 \\ \frac{\text{x}-2{,}5}{5} & ;2{,}5 \leq \text{x} \leq 7{,}5 \\ \frac{17{,}5-\text{x}}{10} & ;7{,}5 \leq \text{x} \leq 17{,}5 \end{cases}$$

$$\mu_{\text{ROE}_{LG}}(\text{x}) = \begin{cases} 0 & ;\text{x} \leq -2{,}5 \text{ or } \text{x} \geq 7{,}5 \\ \frac{\text{x}+2{,}5}{5} & ;-2{,}5 \leq \text{x} \leq 2{,}5 \\ \frac{7{,}5-\text{x}}{5} & ;2{,}5 \leq \text{x} \leq 7{,}5 \end{cases}$$

$$\mu_{\text{ROE}_{NG}}(\text{x}) = \begin{cases} 1 & ;-20 \leq \text{x} \leq -2{,}5 \\ \frac{2{,}5-\text{x}}{5} & ;-2{,}5 \leq \text{x} \leq 2{,}5 \\ 0 & ;\ \text{x} \geq 2{,}5 \end{cases}$$

The representations of fuzzy sets on the input variable of ROE ratio and ROE ratio can be seen on the Figure 5 and Figure 6.

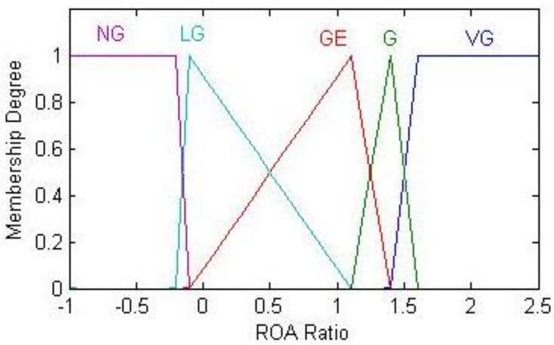

Figure 5: Fuzzy set in ROA variable

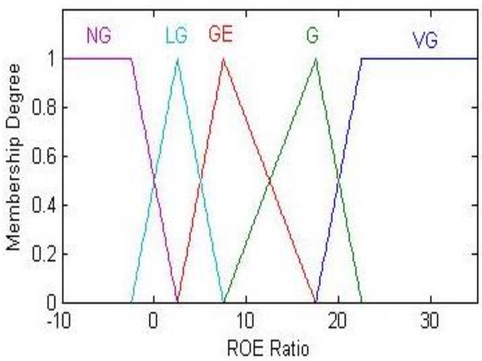

Figure 6: Fuzzy set in ROE variable

The membership functions of fuzzy sets defined on the NIM ratio and CAR ratio are as follows:

$$\mu_{NIM_{VG}}(x)=\begin{cases}0 & ; x\le 2{,}25\\ \frac{x-2{,}25}{5{,}5} & ; 2{,}25\le x\le 7{,}75\\ 1 & ; 7{,}75\le x\le 21\end{cases}$$

$$\mu_{NIM_{G}}(x)=\begin{cases}0 & ; x\le 1{,}75 \text{ or } x\ge 7{,}75\\ \frac{x-1{,}75}{0{,}5} & ; 1{,}75\le x\le 2{,}25\\ \frac{7{,}75-x}{5{,}5} & ; 2{,}25\le x\le 7{,}75\end{cases}$$

$$\mu_{NIM_{GE}}(x)=\begin{cases}0 & ; x\le 1{,}25 \text{ or } x\ge 2{,}25\\ \frac{x-1{,}25}{0{,}5} & ; 1{,}25\le x\le 1{,}75\\ \frac{2{,}25-x}{0{,}5} & ; 1{,}75\le x\le 2{,}25\end{cases}$$

$$\mu_{NIM_{LG}}(x)=\begin{cases}0 & ; x\le -1{,}25 \text{ or } x\ge 1{,}75\\ \frac{x+1{,}25}{2{,}5} & ; -1{,}25\le x\le 1{,}25\\ \frac{1{,}75-x}{0{,}5} & ; 1{,}25\le x\le 1{,}75\end{cases}$$

$$\mu_{NIM_{NG}}(x)=\begin{cases}1 & ; -2\le x\le -1{,}25\\ \frac{1{,}25-x}{2{,}5} & ; -1{,}25\le x\le 1{,}25\\ 0 & ; x\ge 1{,}25\end{cases}$$

$$\mu_{CAR\,VG}(x)=\begin{cases}0 & ; x\le 9{,}5\\ \frac{x-9{,}5}{5} & ; 9{,}5\le x\le 14{,}5\\ 1 & ; 14{,}5\le x\le 182\end{cases}$$

$$\mu_{CAR\,G}(x)=\begin{cases}0 & ; x\le 8{,}5 \text{ or } x\ge 14{,}5\\ x-8{,}5 & ; 8{,}5\le x\le 9{,}5\\ \frac{14{,}5-x}{5} & ; 9{,}5\le x\le 14{,}5\end{cases}$$

$$\mu_{CAR\,GE}(x)=\begin{cases}0 & ; x\le 7{,}5 \text{ or } x\ge 9{,}5\\ x-7{,}5 & ; 7{,}5\le x\le 8{,}5\\ 9{,}5-x & ; 8{,}5\le x\le 9{,}5\end{cases}$$

$$\mu_{CAR\,LG}(x)=\begin{cases}0 & ; x\le 4{,}5 \text{ or } x\ge 8{,}5\\ \frac{x-4{,}5}{3} & ; 4{,}5\le x\le 7{,}5\\ 8{,}5-x & ; 7{,}5\le x\le 8{,}5\end{cases}$$

$$\mu_{CAR\,NG}(x)=\begin{cases}1 & ; 0\le x\le 4{,}5\\ \frac{7{,}5-x}{3} & ; 4{,}5\le x\le 7{,}5\\ 0 & ; x\ge 7{,}5\end{cases}$$

The representation of fuzzy set on the input variable of NIM ratio and CAR ratio can be seen on the Figure 7 and Figure 8.

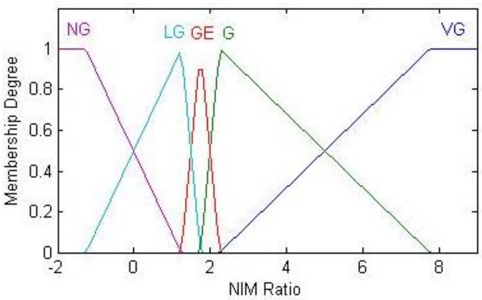

Figure 7: Fuzzy set in NIM variable

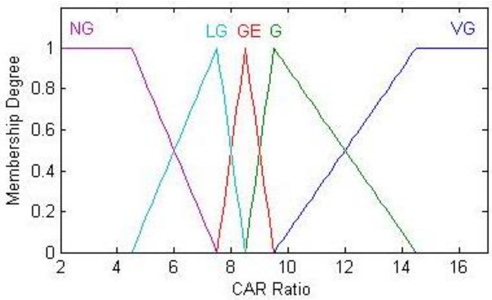

Figure 8: Fuzzy set in CAR variable

B. Constructing fuzzy rules

The result of the performance assessment used in determining fuzzy rule comes from the total of training data with the total of 261. The fuzzy rule which has been made is sequenced and selected. Provided that there are several same rules, one rule is chosen, whereas the other ones are eliminated.

Based on the 261training data, it will be formed 141 fuzzy rules as follows.

1. If NPL is NPL_{SS} (very good) and LDR is LDR_{SS}(very good) and ROA is ROA_{SS}(very good) and ROE is ROE_{SS}(very good) and NIM is NIM_{SS}(very good) and CAR is CAR_{SS}(very good), then $y_1 = b_1$.
2. If NPL is NPL_{SS} (very good) and LDR is LDR_{SS} (very good) and ROA is ROA_{SS} (very good) and ROE is ROE_{SS} (very good) and NIM is NIM_{SS} (very good) and CAR is CAR_{S} (good), then $y_2 = b_2$.

141. If NPL is NPL_{SS} (very good) and LDR is LDR_{SS} (very good) and ROA is ROA_{SS} (very good) and ROE is ROE_{SS} (very good) and NIM is NIM_{KS} (less than good) and CAR is CAR_{SS} (very good), then $y_{141} = b_{141}$

C. Determining constants of consequents of the 141 fuzzy rules.

Based on 141 fuzzy rules, we construct matrix $\boldsymbol{X}$ with size 261x141 as (10). Furthermore, in applying SVD on matrix $\boldsymbol{X}$, the number of nonzero singular value of $\boldsymbol{X}$ are 141 as shown in Figure. 9.

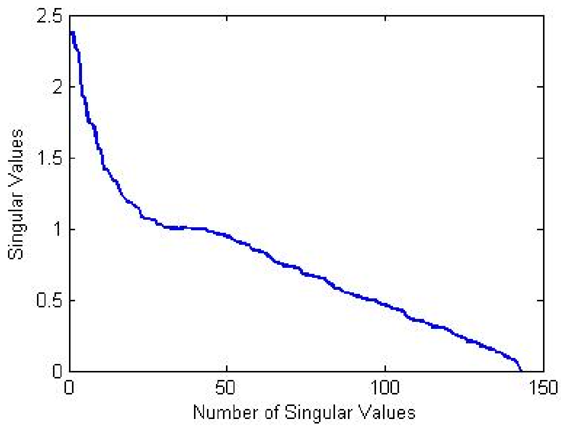

Figure 9.Singular Values of Matrix $\boldsymbol{X}$

Based on the equation (11) we get

$$b = [b_1 b_2 \ldots b_{49} b_{50} b_{51} \ldots b_{141}] = [0\ 0 \ldots 1.0159\ \ 0\ \ -1.0159\ \ 0 \ldots 0]^T$$

D. Determining defuzzification.

Defuzzification is conducted by using equation (5) as follow

$$\boldsymbol{y} = \frac{\sum_{i=1}^{141} \boldsymbol{y}_i\left(\boldsymbol{\mu}_{i1}(\boldsymbol{x}_1)\boldsymbol{\mu}_{i2}(\boldsymbol{x}_2) \ldots \boldsymbol{\mu}_{i6}(\boldsymbol{x}_6)\right)}{\sum_{i=1}^{141} \boldsymbol{\mu}_{i1}(\boldsymbol{x}_1)\boldsymbol{\mu}_{i2}(\boldsymbol{x}_2) \ldots \boldsymbol{\mu}_{i6}(\boldsymbol{x}_6)}$$

$$y = \frac{\begin{array}{c}1.0159\left(\mu_{NPL_G}(x_1)\mu_{LDR_{GE}}(x_2)\mu_{ROA_{VG}}(x_3)\mu_{ROE_G}(x_4)\mu_{NIM_{VG}}(x_5)\mu_{CAR_{VG}}(x_6)\right)- \\ 1.0159\left(\mu_{NPL_G}(x_1)\mu_{LDR_{GE}}(x_2)\mu_{ROA_{VG}}(x_3)\mu_{ROE_{GE}}(x_4)\mu_{NIM_{VG}}(x_5)\mu_{CAR_{VG}}(x_6)\right)\end{array}}{\begin{array}{c}\mu_{NPL_G}(x_1)\mu_{LDR_{GE}}(x_2)\mu_{ROA_{VG}}(x_3)\mu_{ROE_G}(x_4)\mu_{NIM_{VG}}(x_5)\mu_{CAR_{VG}}(x_6)+ \\ \mu_{NPL_G}(x_1)\mu_{LDR_{GE}}(x_2)\mu_{ROA_{VG}}(x_3)\mu_{ROE_{GE}}(x_4)\mu_{NIM_{VG}}(x_5)\mu_{CAR_{VG}}(x_6)\end{array}} \quad (13)$$

The accuracy of model is measured as follows:

$$\text{accuracy} = \frac{\text{the number of the correct data prediction}}{\text{the amount of entirely data}} \times 100\%$$

The formula (13) is applied to analyze bank performance for training and testing data. The accuracy comparison of zero-order TSK, Mamdani, and zero-order TSK with SVD method for analyzing bank performance is shown in Table 4.

Table 4. Comparison of accuracy for some methods

Type of Data	Mamdani method	Zero-Order TSK method	Zero-Order TSK with SVD method
Testing	87,356%	96,16%	99,23%
Training	99,616%	100%	100%

Based on Table 4, the accuracy of Mamdani method for training and testing data are 87,356% and 99,616% respectively. While the accuracy of zero-order TSK method are 96,16% and 100% for training and testing data. Then, the accuracy of zero-order TSK with SVD method are 99,23% for training data and 100% for testing data.

7. Conclusion

The result of this research is that fuzzy model of zero-order TSK using singular value decomposition method gives more accuracy than that of other methods in analyzing the performance of banks in Indonesia. In this research, we assume that every rule has same weight. Furthermore, it is possible that every rule has different weights so that the generated fuzzy model gives more accurate results. Therefore in the next research, we would like to apply weighted rules to analyze the performance of banks.

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