M – 16

Analyzing Of Bank Performance Level Using RGEC And Mamdani Fuzzy System Implemented With Graphical User Interface

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***Abstract*—**Banking industry has become an integral part in operating economic activities in every country. It is one of the most vibrant and growing industries of Indonesia. Analyzing of bank's performance helps them to evaluate and improve their weaker area and to know how far they have satisfied their customer. It also becomes one of the customers' considerations to choice their bank. This research is aimed at explaining how to apply Mamdani fuzzy system to determine the performance of banks in Indonesia and the system is implemented by using Graphical User Interface (GUI). The other aim of this research is to determine the accuracy of bank's performance using Mamdani fuzzy system. The first step is to determine the bank performance that is measured by using RGEC approach (Risk Profile, Good Corporate Governance, Earnings, Capital). The ratios that are used are Non Performing Loan (NPL), Loan to Deposit Ratio (LDR), Return on Assets (ROA), Return on Equity (ROE), Net Interest Margin (NIM), and Capital Adequacy Ratio (CAR). This research is quantitative descriptive research using secondary data. This research uses 109 banks' data with three years period. The data are divided into two parts which 87 banks are for training data and 22 banks are for testing data. The fuzzy system that is used is Mamdani method and we use the centroid method in defuzzification process. Then, the result of fuzzy system is implemented by using Graphical User Interface (GUI).The accuracy of the Mamdani fuzzy system for data training in 2011, 2012, 2013 is respectively 86.2%, 83.9%, 91.95%. The accuracy of testing data in 2011, 2012, 2013 is respectively 95.45%,100%, 100%. It means that the Mamdani fuzzy system can be applied to classify the bank performance in Indonesia.

Keywords: *bank performance, Graphical User Interface, RGEC, Mamdani fuzzy system.*

I. INTRODUCTION

Bank is an institution collecting fund from people in the form of deposit and distributing it to people in the form of credit in order to increase the their quality life. Banking industry has a vital role in improving the economic condition of a country [1]. It is because most of the life sectors related to finances need the banking service so that bank becomes the core of a country's economic matters.

Based on that statement, it is needed to know the performance of banks. Knowing the banks' performance is aimed at keeping the economic stability and becoming the customers' consideration in choosing a bank. Besides, it can be used by Bank Indonesia to supervise a bank. 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 Coorporate Governance, Earning, dan Capital [2].

There are several researches about banks performance that have been done which one of them is by Nadia Iffatul Ulya using RGEC method with Man-Whitney to compare 15 conventional banks to Islamic banks [3]. While, Uddin and Bristy use squared correlation coefficient method (r^2) to analyze five commercial banks in Bangladesh [4]. Then, Shen and Tzeng use DRSA (dominance-based rough set approach) method with Neural Network in the application of financial condition prediction of bank in Taiwan [5]. Nur Artyka uses RGEC method to assess the performance of PT. Bank Rakyat Indonesia in 2011-2013 [6]. Moreover, Anis Ulfah Mustaqim analyzes the performance of 107 banks in Indonesia by

using CAMEL method with Mamdani fuzzy logic [7]. The last is a research conducted by Rani Mita Sari classifying the performances of banks in Indonesia with RGEC method and zero-order Sugeno fuzzy [8].

Fuzzy system can be interpreted as a complete linguistic description (the rule of fuzzy: if-then) that is about a process that can be combined into a model [9]. The phase of fuzzy system is fuzzification, fuzzy inference, and defuzzification. The fuzzy system can be applied into many kinds of field, such as: medical diagnose, control algorithm, decision supporting system, economic, technique, environment, psychology, and many more [10]. Mamdani's fuzzy inference method was among the first control systems built using fuzzy set theory. This research uses fuzzy system with Mamdani inference and and centroid defuzzification as the aids to make a decision in assessing the bank performance in Indonesia. Mamdani method is simple inference method because it has easy calculation and comprehension level [11]. Graphical User Interface (GUI) is used as the connector between the users and fuzzy system that is built to ease the users in operating it.

II. METHODS

The data is obtained from the file of Bank Indonesia and the website of Financial Service Authority. There are 109 banks' data that are collected. The data of those banking names are then given a code like 1, 2, 3,…,109 as the substitute of the names of the researched banks. This researched is conducted for three years so that it is collected 327 banks' data. The RGEC factor is only limited by the risk profile, earnings, and capital. The good corporate governance (GCG) factor is not analyzed because it is qualitative research done by the bank itself (self-assessment) and it is because there is not any data for that factor in the file of Bank Indonesia. The steps of the research are shown by Figure 1 as follows:

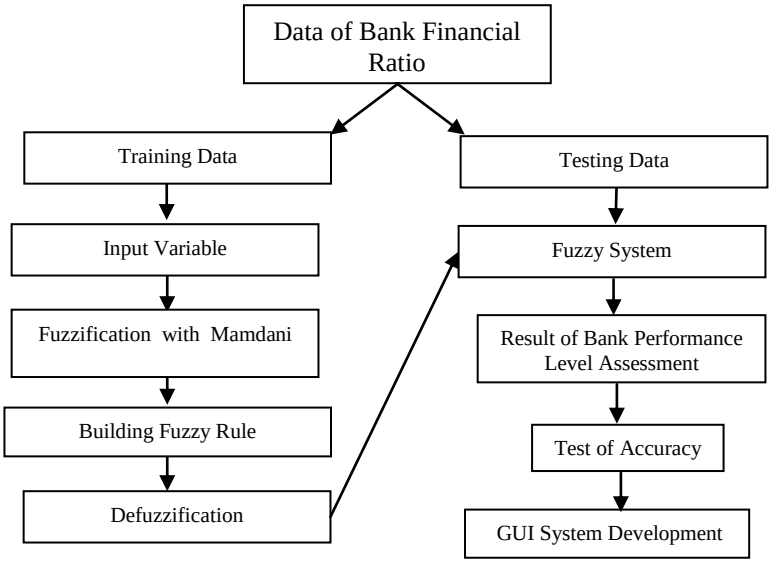

FIGURE 1. THE STEPS OF BANK PERFORMANCE LEVEL ASSESSMENT USING MAMDANI FUZZY SYSTEM

The first is looking for the ratio to measure the factors used in the RGEC method. 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

Ranking	Information	NPL Criteria	LDR Criteria
1	Very good	NPL < 2%	LDR ≤ 75%
2	Good	2% ≤ NPL < 3,5%	75% < LDR ≤ 85%
3	Good enough	3,5% ≤ NPL < 5%	85% < LDR ≤ 100%
4	Less than good	5% ≤ NPL ≤ 8%	100% < LDR ≤ 120%
5	Not good	NPL > 8%	LDR > 120%

SOURCE : BUKU LAPORAN KEUANGAN [12] AND SURAT EDARAN BANK INDONESIAI [13]

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

TABLE 2. MATRIX OF RANKING DETERMINATION CRITERIA OF ROE AND NIM

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

SOURCE: LAMPIRAN II SURAT EDARAN BANK INDONESIA [14] AND SURAT EDARAN BANK INDONESIA [13]

Standart rasio Capital Adequacy Ratio(CAR) can be seen on the Table 3.

TABLE 3. MATRIX OF RANKING DETERMINATION CRITERIA OF CAPITALIZATION

Ranking	Information	Criteria
1	Very good	KPMM > 12%
2	Good	9% < KPMM ≤ 12%
3	Good enough	8% < KPMM ≤ 9%
4	Less than good	6% < KPMM ≤ 8%
5	Not good	KPMM ≤ 6%

SOURCE : SURAT EDARAN BANK INDONESIA [13]

III. RESULTS AND DICUSSION

The first step in assessing the bank performance is looking for each bank's performance by using RGEC method. The performance level of a bank is known through the composite level it has, using the criteria that has been determined on the Table 1, Table 2, and Table 3. After the whole ratio data are collected, the next step is classifying each RGEC ratio into several composite ranks so that it can be determined its own score.

For example is the financial ratio data of the bank code 3 in 2011. The ratio can be classified into suitable composite ranking as it reflected on the Table 4.

TABLE 4. RATIO COMPOSITE RANKING OF BANK CODE 3 YEAR OF 2011

RGEC Ratio	Ratio Value	Composit Ranking
NPL	3,55	3 (very good)
LDR	65,79	1 (very good)
ROA	1,39	2 (very good)
ROE	11,39	3 (very good)
NIM	4,54	2 (very good)
CAR	16,39	1 (very good)

After the result of performance level ranking determination on each RGEC factor is gained, the score is defined to determine the final composite ranking of a bank.

TABLE 5. PERFORMANCE LEVEL OF BANK CODE 3 YEAR OF 2013

RGEC Ratio	Composite Ranking	Score
NPL	3	3
LDR	1	5
ROA	2	4
ROE	3	3
NIM	2	4
CAR	1	5
Total of Score		24

The score total gained by bank code 3 is 24. It means that the bank can be categorized into composite ranking 2 or it shows that the condition of bank 3 is good in general so that the bank is assumed to be able to face the significant negative impacts form the change of business condition or the other external factors.

Based on that performance assessment, the next step can be done that is building the fuzzy system. The followings are the steps of building the Mamdani fuzzy system.

A. Identifying the Set of Universal (U) on the Input and Output

Universal set is the value allowed in fuzzy system operation. There are 87 training data that are used with three years period so that the total of training data is 261 data. Here are the universal set on the input variable: $U_{\text{NPL}} = [0, 13]$, $U_{\text{LDR}} = [0, 621]$, $U_{\text{ROA}} = [-2, 8]$, $U_{\text{ROE}} = [-20, 144]$, $U_{\text{NIM}} = [-2, 21]$, and $U_{\text{CAR}} = [0, 182]$. The universal set on the output is $U_{\text{output}} = [0\ 31]$.

B. Identifying Fuzzy Set on the Input and Output

In this step, the clear set will be transformed into fuzzy set. The process is named fuzzification process. The fuzzy set is transformed by using affiliation function. The affiliation function used on the input of this research is the affiliation function of shoulder curve approach with the combination of affiliation function of triangle and trapezium.

Input variable can be defined into five fuzzy set with the affiliation function of shoulder curve approach. Fuzzy set for bank that have composite ranking 1 given a code SS, composite ranking 2 given code S, composite ranking 3 given code CS, composite ranking 4 given code KS, and composite ranking 5 given code TS. The equation shoulder curve on the NPL and LDR ratio is as follows:

$$\mu_{\text{NPL}_{\text{SS}}}(x) = \begin{cases} 1 & ;0 \le x \le 1{,}5 \\ -x + 2{,}5 & ;1{,}5 \le x \le 2{,}5 \\ 0 & ;x \ge 2{,}5 \end{cases}$$

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

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

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

$$\mu_{\text{NPL}_{\text{TS}}} = \begin{cases} 0 & ;x \le 5{,}5 \\ \frac{x - 5{,}5}{5} & ;5{,}5 \le x \le 10{,}5 \\ 1 & ;10{,}5 \le x \le 13 \end{cases}$$

and

$$\mu_{\text{LDR}_{\text{SS}}}(x) = \begin{cases} 1 & ;0 \le x \le 70 \\ \frac{80 - x}{10} & ;70 \le x \le 80 \\ 0 & ;x \ge 80 \end{cases}$$

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

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

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

$$\mu_{\text{LDR}_{\text{TS}}}(x) = \begin{cases} 0 & ;x \le 110 \\ \frac{x-110}{20} & ;110 \le x \le 130 \\ 1 & ;130 \le x \le 621 \end{cases}$$

The representation of fuzzy set on the input variable of NPL ratio and LDR ratio can be seen on the Figure 2 and Figure 3.

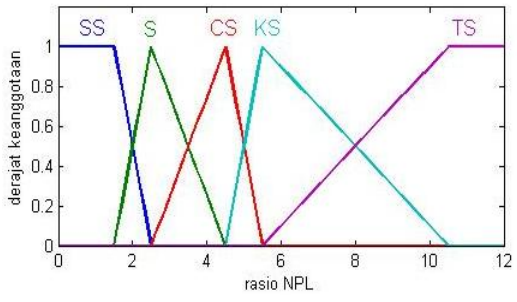

FIGURE 2. FUZZY SET IN NPL VARIABLE

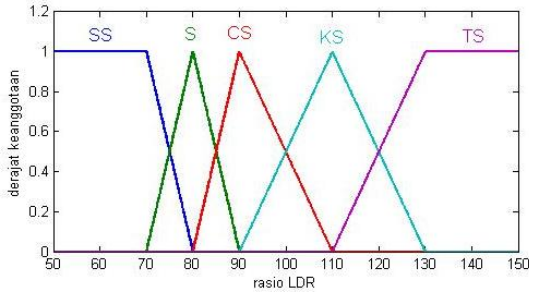

FIGURE 3. FUZZY SET IN LDR VARIABLE

The shoulder curve equation on the ROA ratio and ROE ratio is as follows:

$$\mu_{\text{ROA}_{\text{SS}}} = \begin{cases} 0 & ;x \le 1{,}4 \\ \frac{x - 1{,}4}{0{,}2} & ;1{,}4 \le x \le 1{,}6 \\ 0 & ;1{,}6 \le x \le 8 \end{cases}$$

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

$$\mu_{ROA\ S}(x) = \begin{cases} 0 & ; x \le 1{,}1 \text{ or } x \ge 1{,}6 \\ \dfrac{x-1{,}1}{0{,}3} & ; 1{,}1 \le x \le 1{,}4 \\ \dfrac{1{,}6-x}{0{,}2} & ; 1{,}4 \le x \le 1{,}6 \end{cases}$$

$$\mu_{ROA\ CS}(x) = \begin{cases} 0 & ; x \le -0{,}1 \text{ or } x \ge 1{,}4 \\ \dfrac{x+0{,}1}{1{,}2} & ; -0{,}1 \le x \le 1{,}1 \\ \dfrac{1{,}4-x}{0{,}3} & ; 1{,}1 \le x \le 1{,}4 \end{cases}$$

$$\mu_{ROA\ KS}(x) = \begin{cases} 0 & ; x \le -0{,}2 \text{ or } x \ge 1{,}1 \\ \dfrac{x+0{,}2}{0{,}1} & ; -0{,}2 \le x \le -0{,}1 \\ \dfrac{1{,}1-x}{1{,}2} & ; -0{,}1 \le x \le 1{,}1 \end{cases}$$

$$\mu_{ROA_{TS}}(x) = \begin{cases} 1 & ; -2 \le x \le -0{,}2 \\ \dfrac{-x-0{,}1}{0{,}1} & ; -0{,}2 \le x \le -0{,}1 \\ 0 & ; x \ge -0{,}1 \end{cases}$$

And

$$\mu_{ROE_S}(x) = \begin{cases} 0 & ; x \le 7{,}5 \text{ or } x \ge 22{,}5 \\ \dfrac{x-7{,}5}{10} & ; 7{,}5 \le x \le 17{,}5 \\ \dfrac{22{,}5-x}{5} & ; 17{,}5 \le x \le 22{,}5 \end{cases}$$

$$\mu_{ROE_{CS}}(x) = \begin{cases} 0 & ; x \le 2{,}5 \text{ or } x \ge 17{,}5 \\ \dfrac{x-2{,}5}{5} & ; 2{,}5 \le x \le 7{,}5 \\ \dfrac{17{,}5-x}{10} & ; 7{,}5 \le x \le 17{,}5 \end{cases}$$

$$\mu_{ROE_{KS}}(x) = \begin{cases} 0 & ; x \le -2{,}5 \text{ or } x \ge 7{,}5 \\ \dfrac{x+2{,}5}{5} & ; -2{,}5 \le x \le 2{,}5 \\ \dfrac{7{,}5-x}{5} & ; 2{,}5 \le x \le 7{,}5 \end{cases}$$

$$\mu_{ROE_{TS}}(x) = \begin{cases} 1 & ; -20 \le x \le -2{,}5 \\ \dfrac{2{,}5-x}{5} & ; -2{,}5 \le x \le 2{,}5 \\ 0 & ; x \ge 2{,}5 \end{cases}$$

The representation of fuzzy set on the input variable of ROE ratio and ROE ratio can be seen on the Figure 4 and Figure 5.

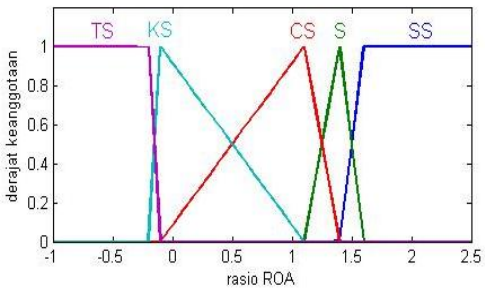

FIGURE 4. FUZZY SET IN ROA VARIABLE

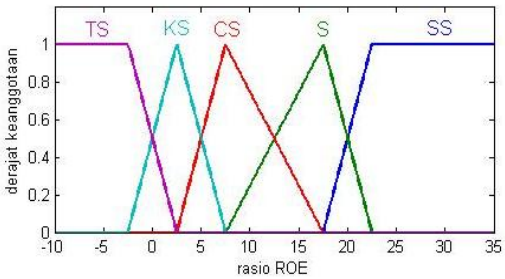

FIGURE 5. FUZZY SET IN ROE VARIABLE

The shoulder curve equation on the ROA ratio and ROE ratio is as follows:

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

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

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

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

And

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

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

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

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

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

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

The representation of fuzzy set on the input variable of ROE ratio and ROE ratio can be seen on the Figure 6 and Figure 7.

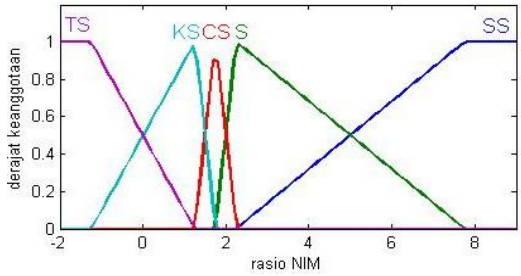

FIGURE 6. FUZZY SET IN INPUT VARIABLE

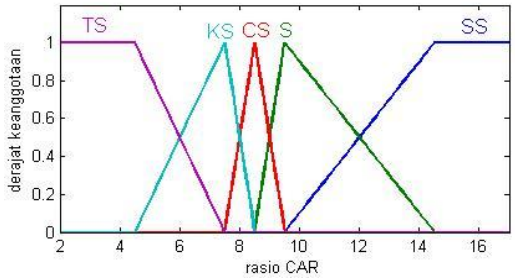

FIGURE 7. FUZZY SET IN INPUT VARIABLE

Output variable is also represented by shoulder curve approach. The value of RGEC ratio has output not good (TS), less than good (KS), good enough (CS), sehat (S), dan very good (SS) with the affiliation function as follows:

$$\mu_{output_{SS}}(x) = \begin{cases} 0 & ; x \le 24{,}5 \\ \frac{x-24{,}5}{6} & ; 24{,}5 \le x \le 30{,}5 \\ 1 & ; 30{,}5 \le x \le 31 \end{cases}$$

$$\mu_{output_{S}}(x) = \begin{cases} 0 & ; x \le 18{,}5 \text{ or } x \ge 30{,}5 \\ \frac{x-18{,}5}{6} & ; 18{,}5 \le x \le 24{,}5 \\ \frac{30{,}5-x}{6} & ; 24{,}5 \le x \le 30{,}5 \end{cases}$$

$$\mu_{output_{CS}}(x) = \begin{cases} 0 & ; x \le 9{,}5 \text{ or } x \ge 24{,}5 \\ \frac{x-9{,}5}{9} & ; 9{,}5 \le x \le 18{,}5 \\ \frac{24{,}5-x}{6} & ; 18{,}5 \le x \le 24{,}5 \end{cases}$$

$$\mu_{output_{KS}}(x) = \begin{cases} 0 & ; x \le 3{,}5 \text{ or } x \ge 18{,}5 \\ \frac{x-3{,}5}{6} & ; 3{,}5 \le x \le 9{,}5 \\ \frac{18{,}5-x}{9} & ; 9{,}5 \le x \le 18{,}5 \end{cases}$$

$$\mu_{output_{TS}}(x) = \begin{cases} 1 & ; 0 \le x \le 3{,}5 \\ \frac{9{,}5-x}{6} & ; 3{,}5 \le x \le 9{,}5 \\ 0 & ; x \ge 9{,}5 \end{cases}$$

The fuzzy set on the output variable can be seen on the Figure 8.

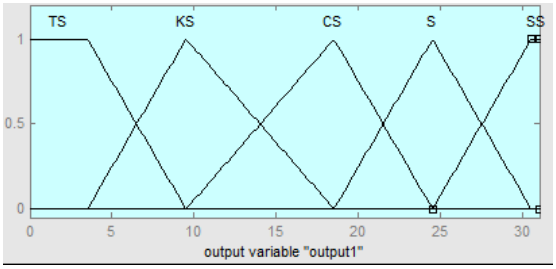

FIGURE 8. FUZZY SET IN OUTPUT VARIABLE

C. Determining Fuzzy Rule

The performance assessment result used in determining fuzzy rule comes form the total of training data of which the total is 261. The fuzzy rule that has been made is sequenced and selected. If there are several same rules, then it is only one that is chosen whereas the other ones are eliminated. The performance level of bank code 3 with the RGEC method has good output. For example is the bank code 3 in 2011 of which the NPL ratio value is 3,55, LDR ratio value is 65,79, ROA ratio value is 1,39, ROE ratio value is 11.39, NIM ratio value is 4,54, and CAR ratio value is 16,39. Then, the fuzzy rule is looked for based on those data. That ratio value is reckoned as *x* value. Based on the five fuzzy set defined on the NPL variable, the NPL affiliation degree can be then known. The function of combination basic operation is used to choose the biggest affiliation degree of those five affiliation degree [15].

$$\mu_{A\cup B}(x) = \max[\mu_A(x), \mu_A(x)], \forall x \in U \quad (1)$$
$$= \max[0; 0{,}475; 0{,}525; 0; 0]$$
$$= 0{,}525.$$

The NPL affiliation degree of bank code 112 in 2011 is 0,525 so that the NPL ratio can be classified into the set of fuzzy NPL_3 or good enough. Do the same thing to the other ratio factors so that it will be created a fuzzy rule i.e. "If NPL is NPL_3 (good enough) and LDR is LDR_1 (very good) and ROA is ROA_2 (good) and ROE is ROE_3 (good enough) and NIM is NIM_2 (good) and CAR is CAR_1 (very good), then the result of bank assessment is good. Furthermore, do the same thing to 260 other banks so that it will be created 141 fuzzy rules as follows.

1 If NPL is VERY GOOD and LDR is VERY GOOD and ROA is VERY GOOD and ROE is VERY GOOD and NIM is VERY GOOD and CAR is VERY GOOD so that the bank assessment is VERY GOOD"
2 If NPL is VERY GOOD and LDR is VERY GOOD and ROA is VERY GOOD and ROE is VERY GOOD and NIM is VERY GOOD and CAR is GOOD so that the bank assessment is VERY GOOD"
3 If NPL is VERY GOOD and LDR is VERY GOOD and ROA is VERY GOOD and ROE is VERY GOOD and NIM is GOOD ENOUGH and CAR is GOOD so that the bank assessment is VERY GOOD"
. .
. .
. .
115 If NPL is GOOD ENOUGH and LDR is VERY GOOD and ROA is SEHAT and ROE is GOOD ENOUGH and NIM is GOOD and CAR is VERY GOOD so that the bank assessment is GOOD"
. .
. .
. .
141 If NPL is LESS THAN GOOD and LDR is GOOD and ROA is NOT GOOD and ROE is NOT GOOD and NIM is VERY GOOD and CAR is GOOD so that the bank assessment is GOOD ENOUGH"

D. Fuzzy Sytsem Inference with Mamdani Method

Mamadani method or *min-max inferencing* uses implication function min or AND and rule aggregation max or OR. The aggregation of fuzzy rule can be searched by using the formula as follows.

$$\mu_{B^k}(y) = \max_k[\min[\mu A_1^k(x_i), \mu A_2^k(x_j)]] \quad (2)$$

For $k = 1,2, \ldots n$, A_1^k and A_2^k states that antecendent pair fuzzy set is number- k, and B^k is a consequent fuzzy set number- k. [16]. For example, bank code 3 has been looked for its own biggest affiliation degree. That affiliation degree forms a fuzzy rule. According to that rule, it can be looked its implication value. The implication value can be looked by determining the minimum value using piece basic operation that is reflected by the Equation (3) [15].

$$\mu A\cap B\ (x) = \min[\mu A(x), \mu A(x)], \forall x \in U \quad (3)$$
$$= \min(0{,}525;1; 0{,}967; 0{,}611; 0{,}583;1)$$
$$= 0{,}525$$

TABLE 6. IMPLICATION FUCNTION RESULT OF BANK CODE 3 IN 2011

Rules	NPL	LDR	ROA	ROE	NIM	CAR	Implikacation α_n
1	0,525	1	0,967	0,611	0,583	1	0,525
2	0,525	1	0,967	0,611	0,583	0	0
..	...	...	...	...	...	...	...
141	0	0	0	0	0,416	0	0

By using the equation (2), it is known that the aggregation value of bank code 3 in 2011 is 0,525. The rules composition result for the bank code 3 in 2011 is shown by the FIGURE 3.

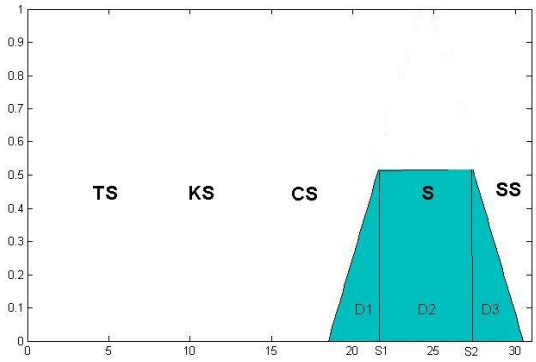

FIGURE 9. The Area of Rules Composition Result of Bank Code 3

Based on that calculation, it is gained that the affiliation function for the rules composition result of bank code 3 is.

$$\mu(x) = \begin{cases} \frac{x-18,5}{6}; & 18,5 \le x \le 21,65 \\ 0,525; & 21,65 \le x \le 27,35 \\ \frac{30,5-x}{6}; & 27,35 \le x \le 30,5 \end{cases} \quad (4)$$

E. Fuzzy System Defuzzification

Deffuzifiaction is aimed at gaining the clear value on the output. The calculation of Centroid defuzzification can be done by using the equation (5) as follows.

$$D^* = \frac{\int_x x\, \mu_B(x)\, dx}{\int_x \mu_B(x)\, dx} \quad (5)$$

Then, the Equation (4) is gotten defuzzification with the Equation (5)

$$D^* = \frac{\int_{18,5}^{21,65} x\left(\frac{x-18,5}{6}\right)dx + \int_{21,65}^{27,35} x(0,525)dx + \int_{27,35}^{30,5} x\left(\frac{30,5-x}{6}\right)dx}{\int_{18,5}^{21,65}\left(\frac{x-18,5}{6}\right)dx + \int_{21,65}^{27,35}(0,525)dx + \int_{27,35}^{30,5}\left(\frac{30,5-x}{6}\right)dx}$$

$$= \frac{\frac{1}{6}\left[\frac{x^3}{3} - 9,25x^2\right]_{18,5}^{21,65} + 0,525\left[\frac{x^2}{2}\right]_{21,65}^{27,35} + \frac{1}{6}\left[15,25x^2 - \frac{x^3}{3}\right]_{27,35}^{30,5}}{\frac{1}{6}\left[\frac{x^2}{2} - 18,5x\right]_{18,5}^{21,65} + 0,525[x]_{21,65}^{27,35} + \frac{1}{6}\left[30,5x - \frac{x^2}{2}\right]_{27,35}^{30,5}}$$

$$= \frac{113,83}{4,647} = 24,495$$

According to that calculation, the value of D*=24,495. It shows that the bank code 3 in 2011 can be categorized into *good* classification or composite ranking 2. Then, the steps having been done can be applied to the whole training and testing data and it will be gained the bank performance assessment result which uses Mamdani fuzzy system. The result of fuzzy system on the training data can be seen on the Table 7 and the testing data can be seen on the Table 8.

TABLE 7. THE RESULT OF FUZZY SYSTEM ON THE TRAINING DATA IN 2011

No	Bank Code	Assessment of Bank Performance		
		y*	*Fuzzy System*	RGEC Assessment
1	1	28,5	Very good	Very good
2	2	27,3	Very good	Very good
...	...	...	...	...
261	87	24,5	Good	Good

TABLE 8. THE RESULT OF FUZZY SYSTEM ON THE TESTING DATA IN 2011

No	Bank Code	Assessment of Bank Performance		
		y*	*Fuzzy System*	RGEC Assessment
1	88	28,8	Very good	Very good
2	89	28,5	Very good	Very good
...	...	...	...	...
66	109	24,5	Good	Good

The accuracy of the fuzzy system that has been created is then examined. The accuracy level is obtained from the comparison between the fuzzy system and the assessment with RGEC.

$$\text{Accuracy} = \frac{\text{Total of correct data}}{\text{Total of incorrect data}} \text{x} 100\% \qquad (6)$$

The correct data is the data producing the same assessment between the fuzzy system and the assessment of RGEC whereas the incorrect data is the data producing different assessment between the fuzzy system and the assessment with RGEC.

From the whole data compared, there are 12 incorrect assessments in 2011, 14 data that are not same in 2012, and seven incorrect data in 2013. The accuracy value of training data in 2011, 2012, 2013 is respectively 86,2%, 83,9% and 91,95%. In the testing data year of 2011, there is one data producing different assessment and in the year of 2012 and 2013, the whole data produce the same assessment between the fuzzy system and the assessment of RGEC. The accuracy value of testing data in 2011, 2012, 2013 is respectively 95,45%, 100% and 100%. Thus, the Mamdani fuzzy system having been created by using fuzzy inference system can be used to assess the performance of banks in Indonesia.

The fuzzy system is then implemented on the graphical user interface (GUI). It is aimed at easing the users in applying the fuzzy system having been created. The result of fuzzy system implementation having been created can be seen on the Figure 10.

FIGURE 10 . VIEWING FUZZY

The GUI system as it is shown above begins with processing the data inputted manually. The data which have been inputted into GUI system is then processed to be classified into composite ranking based on the rule having been made by Bank Indonesia. The assessment result of bank performance on the GUI represents the assessment on the fuzzy system having been created. It means that the assessment result and the level of GUI accuracy are the same with the result of the fuzzy system.

IV. CONCLUSION

A. Conclusion

The implementation of Mamdani fuzzy system in assessing the level of banks' performance in Indonesia starts form dividing the data into 87 banks as training and 22 banks as testing. In this research, the input that is used consisting of NPL, LDR, ROA, ROE, NIM and CAR which each of them use shoulder curve representation. The output result of fuzzy system shows that category of bank performance assessment level is not good, less than good, good enough, good dan very good. There are 141 rules having been created. Fuzzy inference is conducted by using Mamdani system with defuzzification is centroid method. The assessment result with Mamdani fuzzy system is then compared to the classification result based on the RGEC calculation. The result is used to calculate the system accuracy level. The last, the fuzzy system having been created is implemented with Grapichal User Interface (GUI).

The accuracy level gained on the fuzzy system for the training data in 2011, 2012, 2013 is 86,2%, 83,9% dan 91,95%. In the testing data, the accuracy value in 2011, 2012 dan 2013 is respectively 95,45%, 100% dan 100%. Based on the accuracy result that is gained, it can be concluded that Mamdani fuzzy system with Centroid defuzzification and that is implemented with Grapichal User Interface (GUI) is good to be used in assessing the performance level of banks in Indonesia.

B. Suggestions

The result of this research is still far from being perfect. Accordingly, it is still needed to add the newest relevant data and there are several things of the system that still have to be evaluated. The improvement and correction that can be done is adding the total of banking financial ratio data, adding the input variable total, conducting a test with various kinds of affiliation function for each input, inference system and fuzzy defuzzification system method as well as using the other inference methods such as zero-order Tsukamoto Sugeno and zero-order Sugeno.

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