

# Implementation of Fuzzy Tsukamoto Algorithm in Determining the Level of Financial Distress in Microfinance Institutions

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## ABSTRACT

Fuzzy Tsukamoto is one method that is very flexible and tolerant of existing data. Fuzzy Tsukamoto has the advantage of being more intuitive, accepted by many, more suitable for the input received from humans rather than machines. Microfinance institutions are specialized financial institutions established to provide business development services and community empowerment, either through loans or financing in micro-scale businesses to members and the community, deposit management, and the provision of business development consulting services that are not solely for profit. The purpose of this study is to apply the fuzzy Tsukamoto method to determine the level of financial distress in microfinance institutions in the city of Medan based on the variables Liquidity Ratio, Age Firm, and Cumulative Profitability Ratio, Profitability Ratio, Financial Structure Ratio, Capital Turnover Ratio.

**Keywords :** Fuzzy Tsukamoto, Financial Distress, Microfinance Institutions

## I. INTRODUCTION

Financial distress according is a condition where the company's finances are in a state of unhealthy or crisis [1]–[5] Financial distress that is quite disruptive to the company's operations is a condition that must be watched out and anticipated. Based on the explanation above, the author conducted a study of fuzzy inference systems used in determining the level of financial distress in microfinance institutions in Medan. The data used in determining the level of financial distress in microfinance institutions will be used as variables for the process of forming sets, functions of implications, the composition of rules to affirmations. Fuzzy Tsukamoto method has been widely used in solving various problems such as

comparative analysis of fuzzy Tsukamoto method and Mamdani fuzzy method on comparison.

## II. FUZZY LOGIC

Fuzzy logic is a proper way to map an input space into an output space [6]–[8]. The model of fuzzy logic is easier to understand and fuzzy logic if there is data that is not right to have tolerance. In general, fuzzy logic systems have four elements, such as:

- Base rules that contain rules sourced from experts.
- A decision-making mechanism where experts make decisions by applying the knowledge they have.

- Fuzzification process that changes the crisp amount into fuzzy quantities.
- The defuzzification process is the opposite of the fuzzification process, which is to change the fuzzy magnitude of the result of the inference engine, to become a crisp quantity.

In system implementation, fuzzy has three parts, such as fuzzification, fuzzy inference, and defuzzification. However, the defuzzification process is optional, that is, if the conclusion has met or as expected, then there is no need to do a defuzzification process. However, if the conclusion has not been fulfilled, the defuzzification process will still be carried out. Fuzzy logic has a membership function that consists of a limit of input data values and output data values. The definition of the membership function is a graph that contains points from the limit of input data values in a membership value that is worth between 0 and 1.

In the graph the membership function has three parts, such as the core, support, and boundary. The core part is a part of the graph which states the complete area of all fuzzy sets, then if it is expressed in a function where  $x$  is a member of the set  $\mu(x) = 1$ . Furthermore, the second part, which is support, support or support, is a graph that states the region with membership values not 0 from the fuzzy set, then if it is expressed in a function where  $x$  is a member of the set  $\mu(x) > 0$ . Moreover, finally, boundary or boundary. The Boundary in the membership function graph states the minimum limit value and the maximum limit of the fuzzy set, then if expressed in a function where  $x$  is a set member is  $0 < \mu(x) < 1$ .

Fuzzy Tsukamoto method is one method of the Fuzzy Inference System, a decision-making system [9]. In the fuzzy Tsukamoto method use rules or rules in the form of "cause-effect" or "if-then". The method of calculation from the fuzzy Tsukamoto method first is the rule formed representing the fuzzy set, then

calculated the degree of membership by the rules that have been made. After obtaining the membership grade, the alpha predicate ( $\alpha$ ) value is sought by finding the minimum value from the value of the degree of membership. The last step, look for the output value which is the value of crisp ( $z$ ) which is called the defuzzification process, which is expressed in the following equation.

$$Z = \frac{\sum_n^i \alpha(i) \cdot z(i)}{\sum_n^i z(i)}$$

where  $\alpha$  = alpha predicate (minimum value of the value of membership degrees),  $Z_i$  = crisp value obtained from the formula of the degree of membership of the fuzzy set which is the output value, and  $Z$  = centered average defuzzification.

### III. MICRO FINANCIAL INSTITUTIONS

The Financial Services Authority defines Microfinance Institutions as financial institutions specifically established to provide business development and community empowerment services, either through loans or financing in micro-scale businesses to members and the community, deposit management, and the provision of business development consulting services that are not solely seeking profit [10]–[12]. The legal basis for the establishment of Microfinance Institutions in Indonesia is:

1. Law Number 1 of 2013 concerning Microfinance Institutions (MFI Law).
2. Government Regulation Number 89 of 2014 concerning Loan Interest Rates or Yields and the Area of Business Coverage of Microfinance Institutions.
3. Regulation of the Financial Services Authority (Peraturan Otoritas Jasa Keuangan) (POJK):
  - a. POJK Number 12 / POJK.05 / 2014 concerning Business Licensing and Institutions of Microfinance Institutions.

- b. POJK Number 13 / POJK.05 / 2014 concerning Business Implementation of Microfinance Institutions.
- c. POJK Number 14 / POJK.05 / 2014 concerning Guidance and Supervision of Microfinance Institutions.

**Table 1.** Research Variables

Function	Variable Name
Input	T1 (Liquidity - Working Capital to Total Assets)
	T2 (Profitability - Retained earnings / Total Assets)
	T3 (Profitability - ROI)
	T4 (Market Value of Equity / Total Liabilities)
	T5 (Activity - Total Assets Turnover)
Output	Micro Institution Health Level

The objectives of Microfinance Institutions are (1) to increase access to microfinance for the community, (2) to help increase economic empowerment and community productivity and (3) help increase income and welfare of the community, especially the poor and low-income groups. In achieving the goals set, the activities carried out in the form of:

1. The MFI's business activities include business development and community empowerment services, either through loans or financing in micro-scale businesses to members and the community, deposit management, and the provision of business development consulting services.
2. The business activities referred to can be carried out conventionally or based on Sharia Principles.

Based on the previous table, the fuzzy domain can be arranged like the following table.

**Table 2.** Fuzzy Domain

The types of Microfinance Institutions based on the Financial Services Authority include: Bank Desa, Lumbung Desa, Bank Pasar, Bank Pegawai, Bank Kredit Desa (BKD), Bank Kredit Kecamatan (BKK), Kredit Usaha Rakyat Kecil (KURK), Lembaga Perkreditan Kecamatan (LPK), Bank Karya Produksi (BKPD), Badan Usaha Kredit Pedesaan (BUKP), Baitul Maal wa Tamwil (BMT), Baitul Tamwil Muhammadiyah (BTM), and other similar institutions.

**IV. IDENTIFICATION OF FUZZY VARIABLES**

In identifying variables, research has eight input variables and one output variable as shown in the following table.

Variable	Fuzzy set	Range
T1 (Liquidity - Working Capital to Total Assets)	Experience financial distress	< 1
	Gray area	1 < x < 2
	Not experiencing financial distress	> 3
T2 (Profitability - Retained earnings / Total Assets)	Experience financial distress	< 1
	Gray area	1 < x < 2
	Not experiencing financial distress	> 3
T3 (Profitability - ROI)	Experience financial distress	< 1
	Gray area	1 < x < 2
	Not experiencing financial distress	> 3
T4 (Market Value of Equity / Total Liabilities)	Experience financial distress	< 1
	Gray area	1 < x < 2
	Not experiencing financial distress	> 3
T5 (Activity -	Experience financial distress	< 1
	Gray area	1 < x < 2

Total Assets Turnover)	Not experiencing financial distress	> 3
Micro Institution Health Level	Experience financial distress	< 1,81
	Gray area	1,81 – 2,99
	Not experiencing financial distress	> 2,99

### V. RESULT AND DISCUSSION

The data used is the data of Microfinance Institutions in Medan City in the period 2011-2016 have the following variables:

1. Liquidity Ratio
2. Age Firm and Cumulative Profitability Ratio
3. Profitability Ratio
4. Financial Structure Ratio
5. Capital Turnover Ratio

**Table 3.** Data on Micro Institutions Financial Reports

Company	Year	Working Capital	Total Assets	Retained Earnings	EBIT	Market Value of Equity	Total Liabilities	Sales
PT BPR DANAMA NDIRI	2013	8.930	18.060	5.000	58.27	3.00	15.740	2.13
	2014	5.000	54.000	0.000	96.00	0.00	53.000	1.75
	2015	7.578	16.400	5.000	31.96	3.00	13.736	1.91
	2016	5.000	34.000	0.000	96.00	0.00	37.000	5.04
	2017	9.166	16.190	5.000	18.91	3.00	13.336	1.76
	2018	7.000	46.000	0.000	21.00	0.00	22.000	0.38
2019	9.800	17.000	5.000	41.00	3.00	14.200	2.12	

	90.78	53.21	00.00	6.469	0.00	54.889	2.234
	7.00	81.00	0.00	00		0	4.00
2017	8.645	15.94	5.00	18.74	3.00	12.649	1.86
	7.00	61.00	0.00	8.00	0.00	20.00	4.56
2018	16.51	20.70	1.600	(252.88		17.333	
	20.20	34.00	0.00	2.00	3.925	09.00	3.831
2019	19.29	30.83	1.600	1.047		26.477	
	68.93	43.88	0.00	4.011	1.034	04.00	0.19
2020	19.68	29.07	1.600	1.202		23.5	
	80.05	79.56	0.00	1.063	3.675	09.00	4.98
2021	17.99	35.65	1.600	1.301		29.0	
	98.91	71.85	0.00	7.079	5.614	57.00	0.79
2022	16.99	33.69	1.600	(20.7		25.6	
	40.96	61.19	0.00	88.00	8.006	85.451	5.07
2023	31.32	37.90	2.054	1.517		34.3	
	94.94	56.47	5.016	4.063	3.554	50.591	7.79
2024	28.16	34.54	1.384	31.37		31.1	
	28.00	79.00	8.00	32.00	3.384	56.801	8.25
2025	26.25	30.61	22.55	(108.87		28.3	
	0.00	8.70	0.00	03.87	2.225	93.267	7.22
2026	40.25	70.00	6.00	6.00	3.003	0	6.00

		00	00		0)				
		22.	26.		(4				
		23	51	18	2.9		24.0		
		3.5	6.1	2.5	58.	2.48	33.5	6.64	
	20	88.	45.	46.	00	2.54	99.0	5.36	
	16	00	00	00	)	6.00	0	6.00	
		17.	21.		(2				
		02	58	16	0.7		19.1		
		0.2	2.5	1.7	88.	2.46	20.7	5.07	
	20	07.	13.	58.	00	1.75	55.0	3.59	
	17	00	00	00	)	8.00	0	0.00	
BPR MIL ALA		8.4	10.	1.0					
		27.	76	99.	79				
		13	1.3	40	9.3	3.09	7.66	2.73	
		1.0	23.	3.0	18.	9.40	1.92	2.81	
	20	13	0	0	00	3.00	0.00	5.00	
		9.6	12.	1.5	1.2				
		62.	60	60.	69.				
		09	1.8	98	43	3.56	9.04	3.45	
20	14	6.0	02.	7.0	0.0	0.98	0.81	8.13	
		0	00	0	0	7.00	5.00	1.00	
		13.	16.	1.3					
		87	66	59.	99		13.3		
		5.9	3.9	75	8.4	3.35	04.1	3.39	
20	15	93.	43.	5.0	67.	9.75	88.0	9.64	
		00	00	0	00	5.00	0	5.00	
		13.	19.	1.4	1.0				
		11	20	47.	95.		15.7		
		3.0	5.9	75	67	3.44	58.1	4.18	
20	16	89.	54.	5.0	0.0	7.75	99.0	4.35	
		00	00	0	0	5.00	0	3.00	
		11.	17.	1.5	1.2				
		90	26	71.	21.		13.6		
		5.2	7.8	06	33	3.57	96.8	4.25	
20	17	12.	67.	0.0	0.0	1.06	07.0	5.27	
		00	00	0	0	0.00	0	8.00	
BPR MIT RAD ANA MA DAN I		3.5	6.6						
		32.	51.	21	12				
		46	52	1.7	2.6	601.	6.04	1.73	
	20	13	9.0	3.0	68.	91.	972.	9.55	6.97
			0	0	00	00	00	1.00	4.00
		3.7	6.8		(6				
		10.	10.	21	96.				
		11	58	1.7	64	405.	6.40	1.25	
20	14	2.0	1.0	68.	8.0	325.	5.25	1.36	
		0	0	00	0)	00	6.00	3.00	

	15	4.6	6.0	21	(5	346.	5.73	1.01
		30.	83.	1.7	08.	554.	7.37	8.88
		48	92	68.	77	00	4.00	2.00
		6.0	8.0	00	0.0			
		0	0		0)			
		5.8	8.2					
		75.	04.	21	16			
		10	44	1.7	3.4	758.	7.44	1.46
	20	1.0	8.0	68.	72.	390.	6.05	8.19
16		0	0	00	00	00	8.00	1.00
		7.4	10.					
		41.	95	21	24			
		15	5.9	1.7	6.1	1.00	9.95	2.19
20	17	0.0	47.	68.	89.	2.27	3.66	9.12
		0	00	00	00	8.00	9.00	4.00
BPR TAT A PAT UMB AK		5.1	13.	1.4	(3			
		16.	31	89.	56.			
		57	0.8	14	10	510.	12.7	1.74
		7.0	40.	1.0	8.0	859.	99.9	6.36
	20	13	0	00	0	0)	0	7.00
		4.8	10.	1.0				
		51.	43	73.	42			
		42	7.7	78	6.5	926.	9.51	1.83
20	14	1.0	64.	3.0	90.	217.	1.54	8.45
		0	00	0	00	00	7.00	6.00
		5.5	14.	1.2	(8			
		41.	03	09.	2.3			
		87	0.4	44	41.	790.	13.2	2.00
20	15	3.0	77.	8.0	00	552.	25.0	3.11
		0	00	0	)	00	0	4.00
		6.5	14.	1.0				
		32.	85	21.	20			
		50	9.0	52	5.7	978.	13.8	2.41
20	16	7.0	39.	0.0	35.	480.	80.5	9.85
		0	00	0	00	00	0	2.00
		7.5	15.					
		24.	04	93	13			
		55	6.5	7.2	6.4	1.06	13.9	2.62
20	17	0.0	33.	58.	90.	2.74	83.7	1.21
		0	00	00	00	2.00	91.0	1.00
BPR WA HAN A BER SAM A KPU M		8.0	9.8		(2			
		19.	46.	85	8.8			
		37	69	4.3	41.	1.14	8.70	1.76
	20	13	0.0	0.0	83.	00	5.61	1.07
		0	0	00	)	7.00	3.00	0.00
		9.4	11.	92	(5	1.07	10.7	2.33
20	14	11.	87	1.7	4.8	8.28	97.2	9.91
		02	5.5	15.	36.	5.00	70.0	7.00

		3.0 0	55. 00	00 )	00 )		0	
		9.3 26. 95	12. 54 0.7	1.6 09. 22	(6 62. 59		11.1 1.39 50.0	2.63
20 15		5.0 0	98. 00	8.0 0	1.0 0)	0.77 2.00	26.0 0	1.88 7.00
		11. 27 4.2	16. 06 8.6	1.4 87. 14	15 4.7	1.51 2.86	14.5 55.8	3.08
20 16		09. 00	71. 00	0.0 0	66. 00	0.00	11.0 0	7.07 6.00
		13. 18 0.5	17. 96 0.9	1.2 09. 24	29 7.5	1.79 0.75	16.1 70.1	3.44
20 17		73. 00	15. 00	5.0 0	93. 00	5.00	60.0 0	6.11 1.00

Based on the data in the previous table, the Z-Score value is obtained as follows:

**Table 4.** Z-Score value

Z-Score	Information
< 1,81	Experiencing financial distress
1,81 – 2,99	Gray area
> 2,99	Not experiencing financial distress

**Table 5.** Calculation Results of Financial Distress

No	Company	Z-Score	Result
1	PT BPR DANA MANDIRI	1.267760301	Experience Financial Distress
		1.232143962	Experience Financial Distress
		1.331572596	Experience Financial Distress
		1.344797639	Experience Financial Distress
		1.289863945	Experience Financial Distress
2	BPR DUTA ADIARTA	1.357930639	Experience Financial Distress
		1.229400138	Experience Financial Distress

		1.352772445	Experience Financial Distress
		1.077741983	Experience Financial Distress
		0.997886231	Experience Financial Distress
3	BPR EKA PRASETYA	1.456409326	Experience Financial Distress
		1.395401984	Experience Financial Distress
		1.308786148	Experience Financial Distress
		1.32144805	Experience Financial Distress
		1.264240943	Experience Financial Distress
4	BPR MILALA	1.803828139	Experience Financial Distress
		2.209063382	Grey Area
		1.650210142	Experience Financial Distress
		1.44695486	Experience Financial Distress
		1.572528132	Experience Financial Distress
5	BPR MITRADAN A MADANI	1.056949685	Experience Financial Distress
		0.567605706	Experience Financial Distress
		0.882673009	Experience Financial Distress
		1.195912628	Experience Financial Distress
		1.173314475	Experience Financial Distress
6	BPR TATA PATUMBAK	0.662247803	Experience Financial Distress
		1.092749503	Experience Financial Distress
		1.235532577	Experience Financial Distress
		1.363928132	Experience Financial Distress
		0.9244177	Experience Financial Distress
7	BPR WAHANA BERSAMA KPUM	1.329940746	Experience Financial Distress
		1.313060103	Experience Financial Distress

	1.156598838	Experience Financial Distress
	1.239081633	Experience Financial Distress
	1.27420825	Experience Financial Distress

## VI. CONCLUSION

Based on the results and discussion, some conclusions can be drawn. Fuzzy inference system provides a reasonably good process quality value for assessing the level of health of microfinance institutions in Medan. It can be seen in the MSE value generated by the fuzzy inference system almost close to 0, that is BPR MILAL IX. The results of the calculation of fuzzy inference systems are quite useful to be used in assessing the level of health of the company; this can be seen in the value of the level of accuracy of MAPE which is quite small.

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