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Determination of Credit Insurance Premium Due to Default Using the Black-Scholes-Merton Model

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Abstract

Banks are vulnerable to the risk of bad credit or default because customers are unable to pay their debts. Risks that may occur in the future can be in the form of unexpected events and can be experienced by anyone, causing the loan to not be fully repaid. Therefore, it is necessary to have insurance to overcome risks due to default in protecting oneself from the risk of unexpected events, namely credit insurance. This study aims to calculate the premium price using the Black-Scholes-Merton model approach. The data used is arrears data of customers PD. Rural Banks (BPR) Artha Sukapura in 2003-2020. The data is compiled into a cumulative relative frequency distribution table, resulting in a number of random numbers. Based on the cumulative relative frequency distribution table, data simulation was determined using Monte Carlo. Based on the results of the analysis, the simulation data obtained by the standard deviation are relatively stable and lognormal distributed. Then pricing is done to determine the premium price from the sample data. From the results of the calculations in this study, a premium value of IDR 65,316.15 was obtained for arrears of IDR 100,000.00 with a loan of IDR 2,000,000.00.

Keywords: Default Risk; Credit Insurance; Determination of Premiums; Monte Carlo simulation; Black-Scholes-Merton model.

1. Intorudction

Banking is one of the companies in the service sector that has one function, namely channeling funds to the public in the form of loans or credit. When banks provide loans to customers, there are risks that may occur in the future due to something unexpected. Therefore, banks must plan and reduce the risk of default, one way of which is by working with insurance companies.

This research was conducted based on previous research regarding the Black-Scholes-Merton model (Haque et al., 2017; Valverde, 2015; He & Lin, 2021; Pribadi & Susanto, 2015). He & Lin, (2021) studied the Black-Scholes model at European-type put option prices, Valverde (2015) calculated insurance premiums using the Black-Scholes-Merton model as a way of reducing risk due to bankruptcy, Haque et al. (2017) calculated factors of economic uncertainty in iron ore mining projects using the Black-Scholes-Merton formula, and Pribadi & Susanto, (2015) analyzed credit risk using financial ratio analysis using the Merton model.

This research refers to previous research, which is distinguished by its object, namely the place and period of research. In this study, the price of credit insurance premiums in PD was calculated. BPR Artha Sukapura uses the Black-Scholes-Merton model to estimate the probability of default based on historical data.

2. Literature Review

2.1. Credit Insurance

Insurance is an agreement that can provide protection to the insured if a risk occurs in the future due to something unexpected (Filiapuspa et al., 2019). The term "credit" comes from the Latin "credere," which means "trust," where the relationship between the creditor (bank) and the debtor (customer receiving credit) in terms of credit has confidence that the debtor, with an agreement that has been mutually agreed upon, can repay the credit in question (Mulyati, 2018).

Credit insurance is a special insurance protection that can be used to prevent or reduce the risk of lending in the event of bad credit or default.

2.2. Monte Carlo Simulation

Monte Carlo can be used to estimate the total loss, variance, and average given the number of policies sold. This analysis is very useful for estimating premiums and risks for insurance services. According to Huang et al. (2016), the stages of Monte Carlo analysis are as follows:

a) Data Grouping
The obtained data is grouped into classes, then it is calculated how much data goes into each class. Grouping data into data tabulations to facilitate data processing by using data classes linked to each frequency, namely the frequency distribution or frequency table (Bickel & Doksum, 2015).

b) Calculation of the relative frequency distribution
The relative frequency of each class is obtained by dividing the class frequency by the total frequency (Ravid, 2019). The relative frequency distribution table contains data values grouped into class intervals, and each class interval has a frequency number.

c) Calculation of the cumulative relative frequency distribution
The cumulative relative frequency distribution table contains data values obtained from the relative frequency distribution table with the frequencies added up step by step (Ravid, 2021). The steps for presenting data in a cumulative relative frequency distribution table are:
   1) Choose an interval class.
   2) The relative frequency of the selected interval is added to the previous cumulative relative frequency.

d) Determination of random number intervals
The random number interval is determined based on a pre-computed cumulative relative frequency. Random number intervals are used to determine the boundaries between one variable and another.

e) Calculation and generation of random numbers
Random number generation will produce a sequence of numbers, and probabilities can be obtained from the result. Generating random numbers is done using the help of Microsoft Excel software and the syntax =RAND(), which generates random numbers greater than or equal to zero and less than one. The function of this random number is to determine the likelihood of the simulation results.

f) Monte Carlo Simulation
Monte Carlo simulation is performed by comparing generated random numbers with random number intervals.

2.3. Lognormal Distribution Test

The Black-Scholes-Merton model assumes that the data is lognormally distributed, the simulated sample data, which is in a stable condition, needs to be tested for normality, one of which is by using the Kolmogorov-Smirnov method. The Kolmogorov-Smirnov method is the largest absolute difference between$F_n(x)$ the sample empirical distribution function and $F_0(x)$ the cumulative distribution function of the population, or the maximum deviation(D).

$$D = \max|F_n(x_i) - F_0(x)|, \quad i = 1,2,\dots,n \tag{1}$$

The hypothesis to be tested is:
H_0: data with a lognormal distribution
$\boldsymbol{H_1}$: the data is not lognormally distributed
with the decision criteria if the value $D < D_{tabel}$ so H_0 is accepted, meaning that the observed sample distribution has the same distribution as the theoretical distribution (Moni & Shuaib, 2015).

2.4. Black-Scholes-Merton Model

Valverde (2015) states that the Black-Scholes-Merton (BSM) model is used to calculate the probability of bankruptcy for a sample of companies. The Black-Scholes-Merton formula for the European type option is as follows:

$$C = S_0 N(d_1) - Ke^{-rT} N(d_2) \tag{2}$$

and

$$P = Ke^{-rT} N(-d_2) - S_0 N(-d_1) \tag{3}$$

with,

$$d_1 = \frac{\ln(S_0/K) + (r + 0{,}5\sigma^2)T}{\sigma\sqrt{T}} \tag{4}$$

$$d_2 = \frac{\ln(S_0/K) + (r - 0{,}5\sigma^2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T} \tag{5}$$

with C: call option, P: put option, S_0: lose value, K: strike price, T: time, r: risk free interest rate, $N(d_1)$: the cumulative density function of the normal distribution of d_1, $N(d_2)$: the cumulative density function of the normal distribution of d_2.
The price of credit insurance premiums can be calculated using the following equation:

$$Premi = Ke^{-rT}N(-d_2) \quad (6)$$

3. Materials and Methods

3.1. Materials

The purpose of the research is to determine the cost of credit insurance premiums in PD. BPR Artha Sukapura uses the Black-Scholes-Merton model. The data used is secondary data in the form of credit loan arrears data for 2003–2020 as well as additional data in the form of age, gender, and type of collateral for PD customers. BPR Artha Sukapura Easyfit and Microsoft Excel software are used to speed up and simplify the calculation process.

3.2. Methods

The steps taken in this research, namely:

1) Collection of customer data that has failed to pay.
2) Customer arrears data is compiled into a cumulative relative frequency distribution table, yielding a set of random numbers that are used to generate simulation data. The determination of the magnitude of the simulation data loss is carried out repeatedly until stable conditions are obtained, where the standard deviation value of the simulated sample data is close to a certain value.
3) Simulation data that is in a stable condition is tested for normality using the Kolmogorov-Smirnov method, which refers to equation (1).
4) The determination of the amount of the insurance premium due to customer default is carried out using the Black-Scholes-Merton model which refers to equations (4), (5), and (6).

4. Results and Discussion

The following are the data on the amount of arrears in PD. BPR Artha Sukapura, presented in Table 1 and Figure 1.

Table 1: Data on the amount of customer arrears

Years	Number of Custommers	Arrears
2003	1	IDR295,000.00
2004	14	IDR126,728,000.00
2005	3	IDR35,155,000.00
2007	1	IDR6062,000.00
2008	4	IDR11,498,000.00
2009	1	IDR2,498,000.00
2010	3	IDR5,181,000.00
2011	4	IDR14,980,000.00
2012	2	IDR1,826,000.00
2013	4	IDR27,088,000.00
2014	4	IDR11,148,000.00
2015	15	IDR119,772,000.00
2016	21	IDR210,284,500.00
2017	25	IDR203,746,000.00
2018	20	IDR259,987,950.00
2019	20	IDR130,195,500.00
2020	3	IDR16,066,000.00

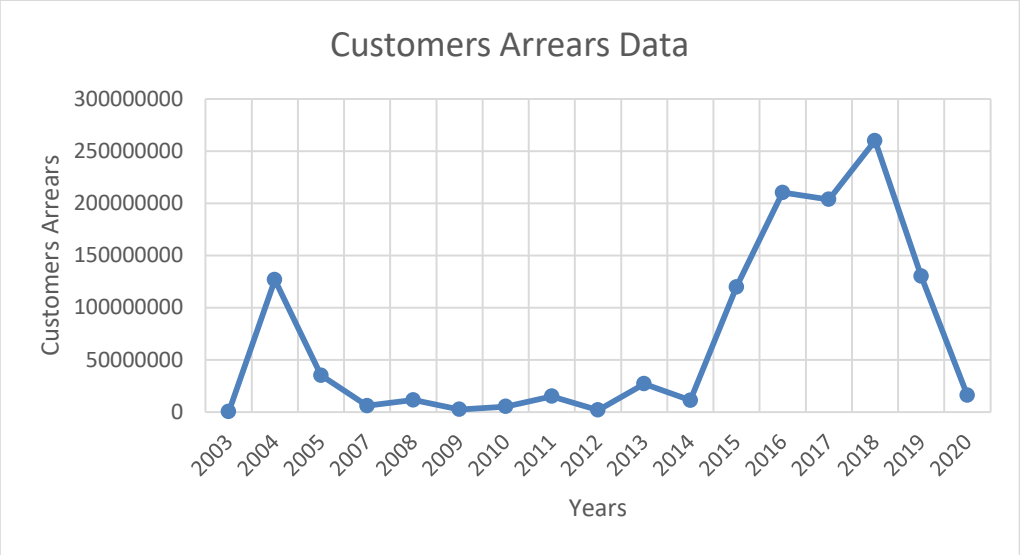

Figure 1: Customers Arrears Data

Based on Table 1 and Figure 1, there are 145 default customers with arrears of IDR 1,182,510,950.00. Customer arrears per year have increased and decreased, the highest arrears of default customers occurred in 2018 with an amount of IDR 259,987,950.00, while the lowest occurred in 2003 with an amount of IDR 295,000.00.

The following is data on the age of customers who fail to pay at PD. BPR Artha Sukapura, presented in Table 2 and Figure 2.

Table 2: Default Customer Age Data

Age	Number of Customers	Age	Number of Customers
24 Year	1	52 Year	4
26 Year	1	53 Year	10
29 Year	1	54 Year	6
33 Year	2	55 Year	3
34 Year	2	56 Year	6
35 Year	1	57 Year	2
36 Year	2	58 Year	10
37 Year	4	59 Year	3
38 Year	2	60 Year	2
39 Year	2	61 Year	5
40 Year	6	62 Year	5
41 Year	3	63 Year	4
42 Year	6	64 Year	4
43 Year	1	65 Year	1
44 Year	5	66 Year	2
45 Year	5	67 Year	1
46 Year	4	68 Year	5
47 Year	5	69 Year	1
48 Year	5	70 Year	1
49 Year	5	81 Year	1
50 Year	2	82 Year	1
51 Year	3		

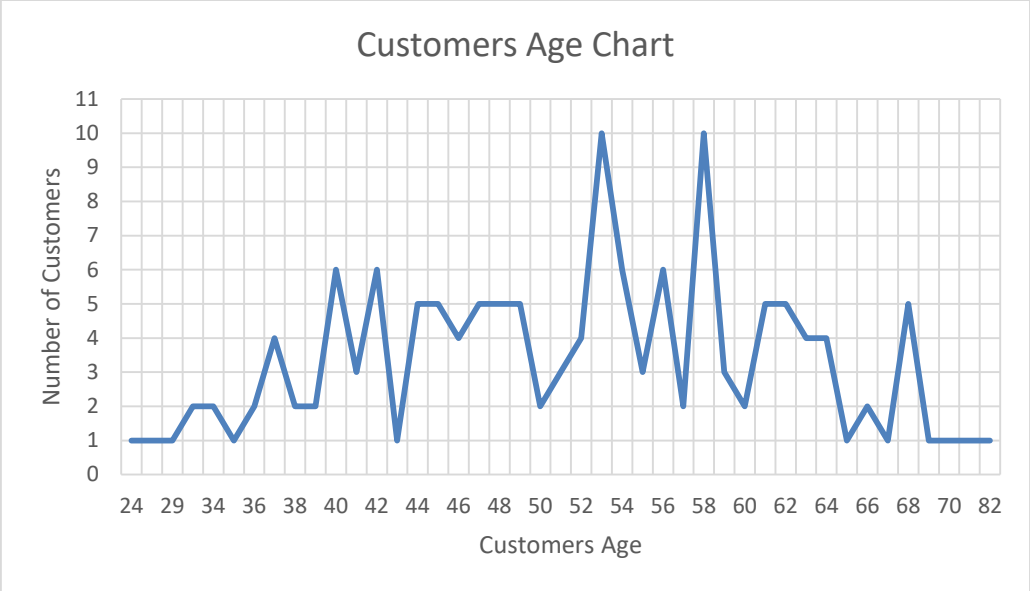

Figure 2: Default Customer Age Data

Table 2 and Figure 2 show that there were 145 default customers, with the lowest and highest ages being, respectively, 24 and 82 years, and the highest number of defaulting customers being 53 and 58 years.

The following is data on the gender of customers who fail to pay at PD. BPR Artha Sukapura, presented in Table 3.

Table 3: Customer Gender Data Defaulted

Gender	Number of Customers
Male	85
Female	60

Table 3 shows that the default customers are mostly male, with a total of 85 customers.

The following is data on the types of collateral for customers who fail to pay at PD. BPR Artha Sukapura, presented in Table 4.

Table 4: Data on Types of Customer Collateral Defaults

Collateral Type	Number of Customers
Motor Vehicles/Cars	6
Land and Buildings	105
No Collateral	34

Table 4 shows that the highest default customers were types of land and building collateral, with a total of 105 customers.

The cumulative relative frequency distribution table calculated with the help of Microsoft Excel software is presented in Table 5.

Table 5: Cumulative Relative Frequency Distribution Table

Intervals	Middle Value	Frequency	Relative Frequency	Cumulatife Relative Frequency	Cumulative Relative Frequency Intervals
0 – 5	2.64166	62	0.427586	0.427586	0 – 0.42759
6 – 11	8.59166	53	0.365517	0.793103	0.4276 – 0.7931
12 – 17	14.59166	16	0.110345	0.903448	0.7932 – 0.90345
18 – 23	20.59166	7	0.048276	0.951724	0.90346 – 0.95172
24 – 29	26.59166	2	0.013793	0.965517	0.95173 – 0.96552
30 – 35	32.59166	2	0.013793	0.97931	0.96553 – 0.97931
36 – 41	38.59166	1	0.006897	0.986207	0.97932 – 0.98621
42 – 47	44.59166	0	0	0.986207	0.98622 – 0.98621
48 – 53	50.50000	2	0.013793	1	0.98622 – 1

Based on Table 5, the highest number of default customers is in the range of IDR 0.00 to IDR 5,000,000.00, with a total of 62 customers. Meanwhile, the lowest number of default customers is in the range of IDR 36,000,000.00 to IDR 41,000,000.00 with one customer. Based on the cumulative relative frequency interval, 270 random numbers were generated for simulation to obtain a relatively stable standard deviation value, presented in Table 6 and Figure 3.

Table 6: Monte Carlo Simulation

Sample Number	Average	Variance	Standard Deviation
50	1.11081	0.70389	0.83898
60	1.06797	0.647488	0.804666
70	1.04436	0.6186	0.786511
80	1.10765	0.640296	0.800185
90	1.14437	0.632903	0.795552
100	1.15907	0.647364	0.804589
110	1.16210	0.727451	0.852907
120	1.19507	0.791096	0.889436
130	1.23805	0.973531	0.986677
140	1.23332	0.943833	0.971511
150	1.25508	0.971674	0.985735
160	1.23992	0.938937	0.968988
170	1.23787	0.91067	0.95429
180	1.23476	0.900059	0.948714
190	1.24004	0.880705	0.938459
200	1.26869	0.999133	0.999566
210	1.26771	1.017779	1.00885
220	1.30266	1.057788	1.028488
230	1.31129	1.037792	1.018721
240	1.32539	1.048401	1.023914
250	1.31894	1.027846	1.013827
260	1.31352	1.007406	1.003696
270	1.31230	0.988868	0.994418

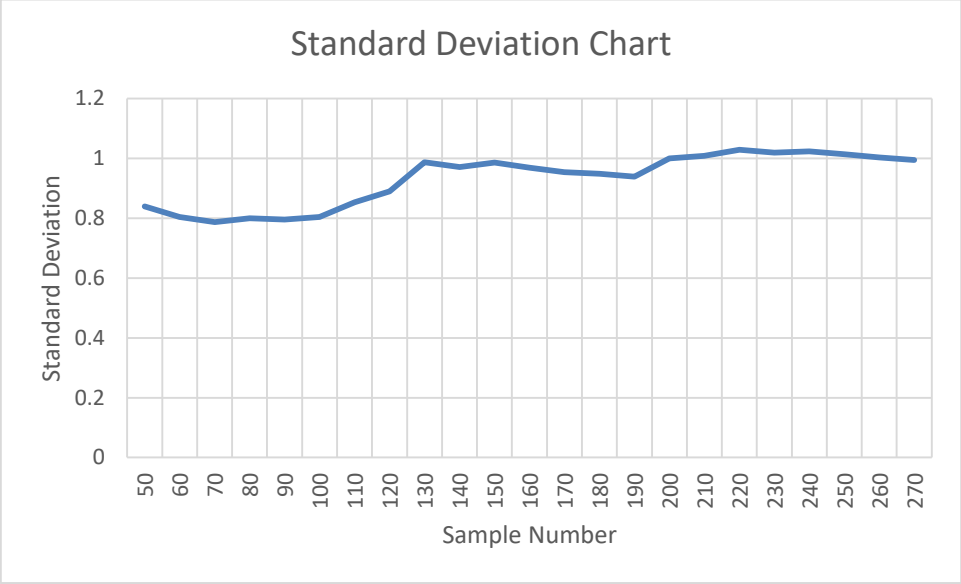

Figure 3: Standard Deviation of Simulation Results

Figure 3 shows that, starting from the number of repetitions of 240 to 270 data points, the standard deviation is relatively stable. Therefore, the simulation can be stopped. Simulation data with a relatively stable number of 270

were tested for a lognormal distribution by making a histogram, assisted by EasyFit software, as presented in Figure 4.

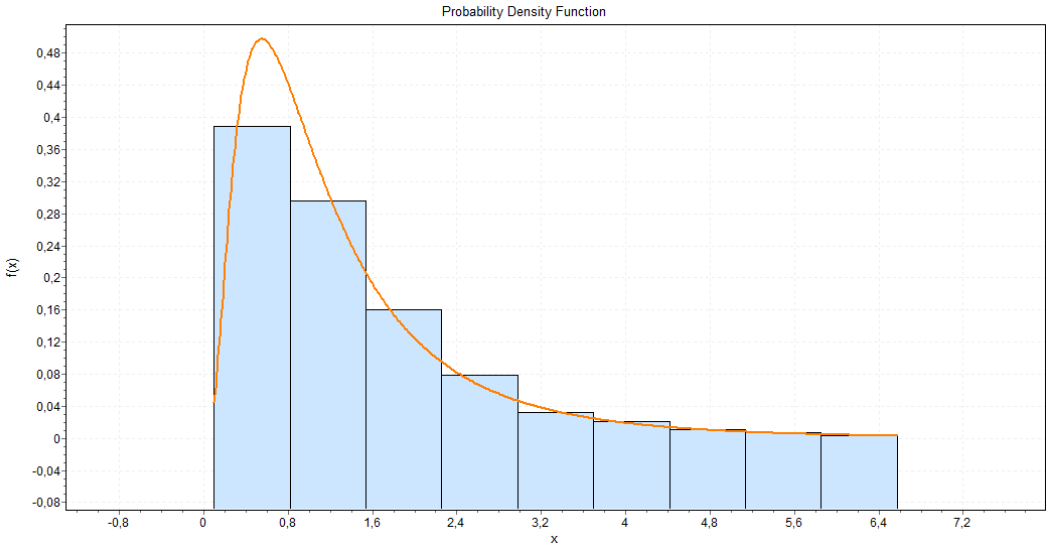

Figure 4: Simulation Histogram

Based on Figure 4, it can be assumed that the simulation data follows a lognormal distribution. Next, the Kolmogorov-Smirnov test is carried out, which refers to Sub-Chapter 2.3, with the help of EasyFit software.

Table 7: Kolmogorov-Smirnov Test Simulation Data

Kolmogorov-Smirnov Normality Test Results		
Simulation Data	Test Statistics (D)	0.0351
	D_{table}	0.08265
	Result	$D < D_{table}$ *or* 0.0351 < 0.08265
	Conclusion	$H_{0\ \text{is}}$ accepted, lognormally distributed simulation data

Figure 4 and Table 7 show that the data is Lognormally distributed. Based on the simulation data of 270 samples, the premium value can be calculated, which refers to equation (6), as follows:

S_0 : 0.1 (Based on data on the smallest arrears of PD customers. BPR Artha Sukapura in millions)
K : 1.31230 (Based on an average of 270 samples)
r : 5.5% per tahun
σ^2 : 0.988868 (Based on the variance of 270 samples)
σ : 0.994418 (Based on the standard deviation of 270 samples)
T : 0.083 years

$$d_1 = \frac{\ln(S_0/K) + (r + 0{,}5\sigma^2)T}{\sigma\sqrt{T}}$$

$$= \frac{\ln(0.1/1.31230) + \left(0.055 + (0.5 \cdot 0.988868)\right)0.083}{0.994418\sqrt{0.083}}$$

$$= -8.82674$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

$$= -8.82674 - 0.286489$$

$$= -9.11323$$

$N(-d_2)$: 1

$$\text{Premium} = Ke^{-rT}N(-d_2)$$

$$= 1.31230\left(e^{-0.055(0.083)}\right)$$

$$= 1.306323 \text{ (in millions)}$$

$$= IDR\ 1{,}306{,}323.00$$

The premium is calculated using the smallest arrears PD. BPR Artha Sukapura, namely $S_0 = 0.1$ million or IDR 100,000.00 for a loan amount of IDR 2,000,000.00, so the premium charged (unit premium) is:

$$\text{Unit premium} = \frac{\text{IDR } 100{,}000.00}{\text{IDR } 2{,}000{,}000.00} \times \text{IDR } 1{,}306{,}323.00$$

$$= \text{IDR } 65{,}316.15$$

therefore, for a loan amount that is not IDR 2,000,000.00, the calculation of the unit premium is the ratio between the arrears and the loan multiplied by the premium value.

5. Discussion

Based on Table 1 and Figure 1, there are 145 default customers with arrears of IDR 1,182,510,950.00. Customer arrears per year have increased and decreased; the highest arrears of default customers occurred in 2018 with an amount of IDR 259,987,950.00, while the lowest occurred in 2003 with an amount of IDR 295,000.00. Table 2 and Figure 2 show that there were 145 default customers, with the lowest and highest ages being, respectively, 24 and 82 years, and the highest number of defaulting customers being 53 and 58 years. Table 3 shows that the default customers are mostly male, with a total of 85 customers. Table 4 shows that the highest default customers were types of land and building collateral, with a total of 105 customers.

Based on Table 5, the highest number of default customers is in the range of IDR 0.00 to IDR 5,000,000.00, with a total of 62 customers. Meanwhile, the lowest number of default customers is in the range of IDR 36,000,000.00 to IDR 41,000,000.00 with one customer. Based on the cumulative relative frequency interval, 270 random numbers were generated for simulation to obtain a relatively stable standard deviation value. Figure 3 shows that, starting from the number of generated data points between 240 and 270, the standard deviation is relatively stable. Therefore, the simulation can be stopped. Simulated data with a relatively stable number of 270 was tested for a lognormal distribution with the help of EasyFit software. Figure 4 and Table 7 show that the data has a lognormal distribution.

The price of the credit life insurance premium due to default in PD. BPR Artha Sukapura is IDR 65,316.15 for arrears of IDR 100,000.00 with a loan of IDR 2,000,000.00. The results of the premium calculation are used as a reference in determining the price of life insurance premiums that must be paid every month.

6. Conclusion

There were 145 defaulted customers with arrears of IDR 1,182,510,950.00. Customer arrears per year have increased and decreased, the highest arrears of default customers occurred in 2018 with an amount of IDR 259,987,950.00, while the lowest occurred in 2003 with an amount of IDR 295,000.00. Based on the calculation of the price of credit life insurance premiums due to default using the Black-Scholes-Merton model, the price of credit life insurance premiums due to default in PD. BPR Artha Sukapura is IDR 65,316.15 for arrears of IDR 100,000.00 with a loan of IDR 2,000,000.00. The results of the premium calculation are used as a reference in determining the price of life insurance premiums that must be paid every month.

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