

Advancing Sharia Insurance Product for Natural Disaster Risks: A Collective Risk Model Approach

Trecy Elisabet Tioralina Saragih^{1*}, Alfonsius Lintang², Chintya Luminar Sinaga³

^{1,2,3}Department of Mathematics, Universitas Brawijaya, Malang, Indonesia

*Corresponding email: saragih¹trecy3@gmail.com

Abstract

Sharia insurance (*takaful*) serves as a means to promote solidarity and shared responsibility, helping protect individuals from unexpected risks by transferring or minimizing these risks through coverage provided by insurance companies. Sharia insurance is grounded in the concept of *ta'awun* which leads to mutual assistance and aims to eliminate forbidden elements in conventional insurance practices such as interest (*riba*), uncertainty (*gharar*), and gambling (*maysir*). Although interest rates are not used to calculate the present value of benefits, sharia insurance products can be improved through actuarial modelling based on expected risk levels and historical data. This paper creates a sharia insurance model for natural disasters of floods and earthquakes using the Collective Risk Model (CRM), with natural disaster frequency data distributed Poisson and natural disaster loss amounts distributed Weibull 3-Parameters. The result reflects the contribution value calculated using the expectation principle and standard deviation of total natural disaster losses. This study also provides a mathematical table as a model for applying the CRM's contribution value to sharia insurance for natural disasters of floods and earthquakes. This table will detail how funds contributed by policyholders are managed, including the percentages allocated to personal accounts, the *tabarru'* (donation) account, and *ujrah* (management fees), as well as the amounts of profit and benefits accrued to policyholders. This breakdown aims to promote transparency and fairness in sharia-compliant insurance for companies and policyholders, ensuring that fund contributions are managed equitably.

Article History:

Received: 27 February 2025

First Revised: 9 May 2025

Accepted: 7 June 2025

Published: 31 July 2025

Keywords:

CRM, Natural disaster, Sharia insurance

1. INTRODUCTION

Otoritas Jasa Keuangan [1] explains that insurance is an agreement between the policyholder (insured) and the insurance company (insurer), where the insured pays a premium and will receive benefits from the company for failures that occur by the policy agreement. Based on the type of management, insurance is divided into two categories, namely conventional insurance and sharia insurance. In contrast to conventional insurance, sharia insurance operates with a sharia values-based approach, which emphasizes the principles of mutual assistance (*ta'awuni*) and mutual protection (*takaful*) between each participant. This principle is realized through the formation of the *tabarru'* fund which aims to eliminate prohibited elements such as interest (*riba*), uncertainty (*gharar*), and gambling (*maysir*).

As a country with a majority Muslim population, Indonesia has great potential to develop sharia insurance as one of the superior products in the insurance industry. Based on data from World Population Review [2], Indonesia is ranked second with the largest Muslim population in the world. However, in reality, public interest in sharia insurance in Indonesia is still minimal compared to conventional insurance. Apart from the fact that there is still a perception that sharia insurance is only for certain religions, the minimal use of sharia insurance in Indonesia can be caused by the lack of variety of products offered.

Sharia insurance products are grouped into three main models, namely *wakalah*, *mudharabah*, and hybrid NuHtay, S. N., et al. [3]. The Hybrid model is the most commonly used because it integrates the principles of *wakalah* (agency) and *mudharabah* (profit sharing). In this model, *tabarru'* fund are distributed to the company as an upfront agency fee (*ujrah*) for managing fund according to the *al-Wakalah* principle, while still providing a share of investment profits based on *al-Mudharabah* principles. Based on the business unit, sharia insurance products are classified as family *takaful* (life insurance), general *takaful* (loss insurance), and *retakaful* (reinsurance).

In establishing a detailed calculation model for insurance products, one approach that can be used is the Collective Risk Model (CRM). CRM is a model applied in actuarial science to calculate aggregate claims or losses that may occur during a certain policy period, thus providing a systematic framework for forming a calculation model scheme. Sharia natural disaster insurance is a general *takaful* product that can be modelled using CRM. This model allows for the collective distribution of disaster risk thereby reducing the individual risk burden on each participant. In line with the concepts of mutual assistance (*ta'awuni*) and mutual protection (*takaful*) in sharia insurance, the implementation of CRM guarantees the availability of *tabarru'* funds collected collectively to cover losses due to natural disasters in the future based on historical data. The development of sharia natural disaster insurance also needs to be carried out considering the geographical characteristics of Indonesia which is in the ring of fire area, making it vulnerable to various natural disasters, such as earthquakes. Apart from that, floods are also the most frequent natural disasters in Indonesia. Based on data from Badan Nasional Penanggulangan Bencana [4], from January 1 to November 1, 2024, Indonesia has experienced flooding 843 times. This condition emphasizes the importance of having insurance products that can protect customers from the risk of natural disasters of floods and earthquakes.

Several previous studies formed the basis of this research. Cahyandari, R., et al. [5] have developed a mathematical model for the *mudharabah* scheme. This model is designed to analyze and predict various risks that a company may face in the future so that it can help companies formulate policies to minimize risks. However, the model used does not focus on natural disaster conditions, such as floods and earthquakes. Apart from that, research from Cahyandari, R., et al. [6] also developed a model for the hybrid scheme but does not include a model that can be used to calculate aggregate claims or losses incurred. Meanwhile, Sukono, et al. [7] have used CRM to determine natural disaster insurance premiums. However, this research has not been applied to the concept of sharia insurance. Based on previous research, there has been no research that applies CRM in the context of sharia insurance. Therefore, this research aims to develop a sharia insurance product calculation scheme, especially for natural disasters of floods and earthquakes using a CRM approach.

2. METHODS

Data collection in this study was carried out using secondary data obtained from the National Disaster Management Agency (BNPB) and Emergency Events Database (EM-DAT). Data includes information on the number of disaster events and losses that occurred in Indonesia during the period 2000-2024. This research specifically focuses the analysis on floods and earthquakes. Data processing was conducted by using Minitab software and Python programming language. The steps used in this research are described as follows.

2.1 Frequency of Natural Disasters

The first step is to estimate the frequency distribution model of natural disasters, which is assumed following the Poisson process. Poisson distribution is a unique distribution where both the expectation and the variance have the same value, Taylor, H. M. and S. Karlin [8]. Statistically, the frequency of natural disasters (such as floods and earthquakes) is often treated as a Poisson process due to its inherent characteristics within a specific time interval (e.g., annually or monthly).

On the other hand, the Poisson process is a stochastic process that models the number of events in a fixed time interval following a Poisson distribution. Given Poisson process of rate, $\lambda > 0$, is an integer valued stochastic process $\{N(t); t \geq 0\}$, with the expectation

$$E[N(t)] = \lambda t \quad (1)$$

and the variance

$$Var[N(t)] = \lambda t. \quad (2)$$

2.2 Distribution of the Amount of Loss

Parameters of the 3-Parameters Weibull distribution is used to determine the expected value and variance of the magnitude of natural disaster losses by Maximum Likelihood Estimation (MLE). Weibull distribution is commonly used to determine time to failure in insurance, Walpole, R. E. and R. H. Myers [9]. The three-parameter Weibull distribution includes a threshold (location) parameter (γ) in addition to the parameter shape (k) and scale (λ). This enhancement makes it particularly useful for cases like natural disaster modelling, where events often have a non-zero threshold before they are observed or cause damage. Its density function with three parameters can be given by

$$f(x; \lambda, k) = \begin{cases} \frac{k}{\lambda} \left(\frac{x - \gamma}{\lambda}\right)^{k-1} e^{-\left(\frac{x-\gamma}{\lambda}\right)^k}, & x \geq 0 \\ 0, & x < 0 \end{cases}$$

with the expectation

$$E(X) = \gamma + \lambda \Gamma\left(1 + \frac{1}{k}\right) \quad (3)$$

and the variance

$$Var(X) = \lambda^2 \left[\Gamma\left(1 + \frac{2}{k}\right) - \Gamma^2\left(1 + \frac{1}{k}\right) \right]. \quad (4)$$

2.3 Anderson-Darling Test

The Anderson-Darling (AD) test is a type of goodness-of-fit test used to assess how well a set of data fits a specified distribution. The AD statistic measures the deviation between the observed data points and the expected values based on the chosen theoretical distribution, Jäntschi, L. and S. D. Bolboaca [10]. This test uses a p -value to evaluate the goodness of fit under the null hypothesis that the data follow the specified distribution. Based on a given significance level (α), the decision rule is as follows:

If $p \leq \alpha$: the data do not follow the tested distribution (reject H_0).

If $p > \alpha$: there is insufficient evidence to conclude that the data deviate from the distribution (fail to reject H_0).

2.4 Collective Risk Model

Collective Risk Model (CRM) is a commonly used model in actuarial science to calculate aggregate claims or losses occurring in a fixed time period of policy. Klugman, S. A., *et al.* [11] construct CRM using S sum of aggregate losses, of a random number N , of individual payment amounts (X_1, X_2, \dots, X_N). Hence,

$$S = X_1 + X_2 + \dots + X_N, \quad N = 0, 1, 2, \dots$$

where $S = 0$ when $N = 0$. Since the N represents the number of claims and X_i are the amount of claims that assumed to be independent and identically distributed (i.i.d), the expectation for aggregate losses in CRM can be defined as

$$E(S) = E(N)E(X)$$

with variance

$$Var(S) = E(N)Var(X) + Var(N)[E(X)]^2.$$

Alongside with the Poisson process and Weibull distribution in equations (1), (2), (3), and (4), the expectation for aggregate losses can be written as

$$E[S(t)] = E[N(t)]E[X(t)] = \lambda \left(\gamma + \lambda \Gamma \left(1 + \frac{1}{k} \right) \right) \quad (5)$$

with variance as

$$\begin{aligned} Var[S(t)] &= E[N(t)]Var[X(t)] + Var[N(t)][E[X(t)]]^2 \\ &= \lambda \left(\lambda^2 \left[\Gamma \left(1 + \frac{2}{k} \right) - \Gamma^2 \left(1 + \frac{1}{k} \right) \right] \right) + \lambda \left(\gamma + \lambda \Gamma \left(1 + \frac{1}{k} \right) \right)^2. \end{aligned} \quad (6)$$

2.5 Contribution Calculation Model

According to Klugman, S. A., et al. [11], premium is the amount of money that insured pay as compensation for taking on risk. In *takaful*, this is closely linked to the contribution that is paid by participants. From the perspective of the company as the insurer, it is clear that the contribution must at least cover the anticipated claims so that the company will not face a great loss at any change. Djuric, Z. [12] also explains two methods to calculate premium (contribution), namely expected value principle and standard deviation principle. The principle of the expected value sets the premium to cover the expected value of the loss (claims) with an additional loading factor to account for administrative costs, profit margins, and risk. According to this principle,

$$P_E = (1 + \rho) E(S) \quad (7)$$

where $\rho > 0$ and represents the loading factor. Due to a high heterogeneity of accepted risks in non-life insurance, the principle of standard deviation determines premium as the expected value and standard deviation of the loss. This can be written as

$$P_{STD} = E(S) + \rho [Var(s)]. \quad (8)$$

This principle ensures that premiums are sufficient not only to cover the expected losses but also to provide a buffer for unexpected fluctuations.

3. RESULT AND DISCUSSION

3.1 Descriptive Statistics Analysis

Descriptive statistical analysis was conducted to provide an overview of the occurrence and financial impacts of flood and earthquake disasters in Indonesia. This study used Minitab for data visualization and calculating descriptive statistics. Data on frequency of floods and earthquakes in Indonesia from 2000-2024 was obtained from the National Disaster Management Agency (BNPB), while the amount of loss was taken from Emergency Events Database (EM-DAT).

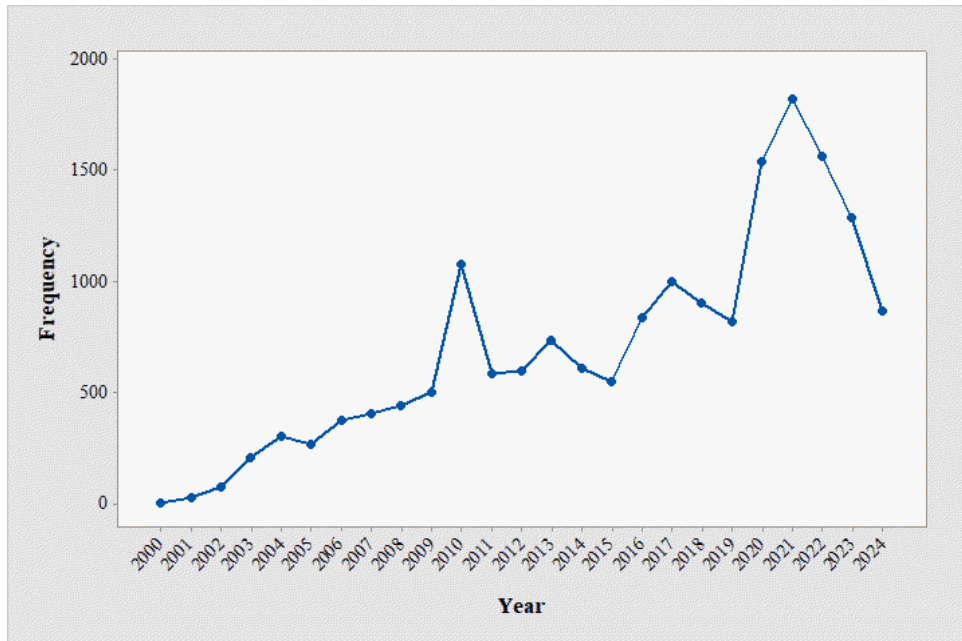


Figure 1. Frequency of floods and earthquakes

Figure 1 shows that the frequency of floods and earthquakes in Indonesia considerable variability over time and increase gradually from 2000 to around 2010. A notable surge is seen around 2019–2021, after which the frequency declines sharply again. This pattern may suggest periodic disaster clusters or improved reporting mechanisms in later years.

Table 1. Statistic descriptive of frequency of floods and earthquakes

Mean	Standard Deviation	Maximum	Minimum	Median
695.3	484.4	1,818	4	599

Table 1 indicates that the maximum frequency recorded is 1,818 occurrences, happened around 2021, representing a peak year for disaster events. The mean frequency over this 25-year period is around 695 events per year, with a standard deviation of 484.4 indicating a relatively high spread or variability in the data.

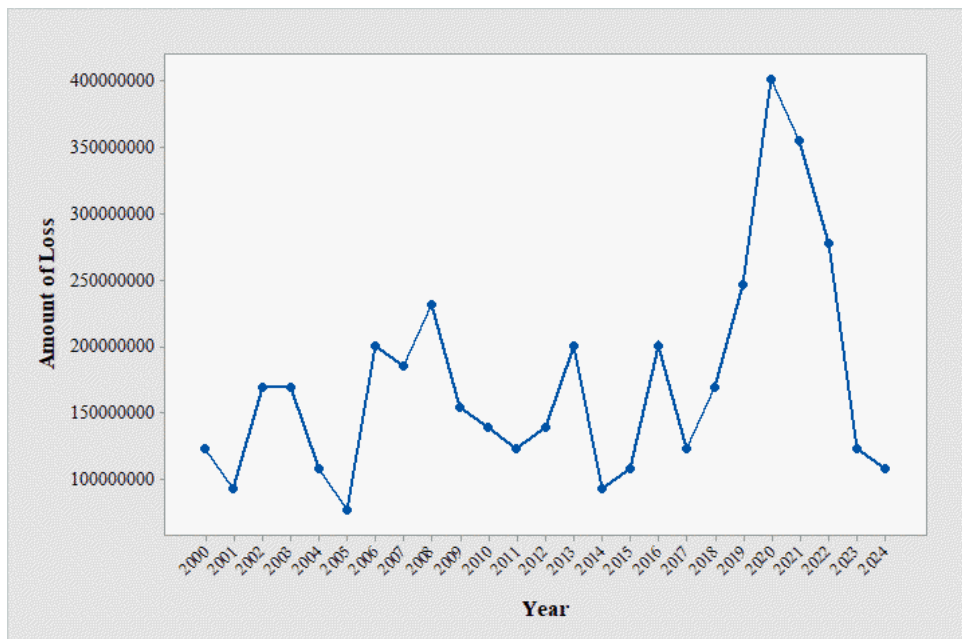


Figure 2. Amount of loss due to floods and earthquakes

Figure 2 shows that annual amount of loss due to floods and earthquakes in Indonesia during 2000-2024 has significant variability. The peak of loss is around 2020-2021, reflecting the highest recorded losses which aligns with the maximum of frequency on Figure 1.

Table 2. Statistic descriptive of amount of loss (IDR)

Mean	Standard Deviation	Maximum	Minimum	Median
172,993,520	80,382,752	401,592,100	77,229,250	154,458,500

Table 2 describes the average loss stands at approximately IDR 172.99 million, with a standard deviation of around IDR 80.38 million, indicating a wide spread of values and the presence of several years with extreme losses. The maximum recorded loss reaches IDR 401.59 million, while the minimum is IDR 77.23 million, showing the diverse impact natural disasters can have from year to year.

3.2 *Estimated Disaster Frequency Distribution Model*

The Poisson process approach is used to estimate the frequency distribution model of natural disasters. In this method, the initial step involves determining the rate parameter (λ), which represents the average number of floods and earthquakes in a given period. The natural disaster frequency data analyzed covers the time span from January 2000 to December 2024, assuming the data is valid for the time interval $t = [0,25)$.

$$\lambda = \frac{1}{n} \sum_{i=1}^n X_i = \frac{4 + 30 + 74 + \dots + 867}{25} = 695.32$$

The analysis results show that the incidence rate of natural disasters is 695.32 events per year. This parameter reflects the annual average frequency of floods and earthquakes over the past 25 years in Indonesia. Using this value, the expectation and variance of the frequency data were calculated to get the distribution of natural disaster events. The expected frequency of natural disasters was recorded as

$$E[N(t)] = (695.32)(1) = 695.32$$

while the variance is

$$Var[N(t)] = (695.32)(1) = 695.32$$

Based on the calculation results, the average number of claims expected to arise due to floods and earthquakes in one year is approximately 695.32 cases. The same variance value of 695.32 indicates that the frequency data has relatively uniform distribution characteristics in this Poisson process.

3.3 *Estimated Disaster Losses Distribution Model*

Distribution models for estimating the magnitude of losses due to natural disasters were identified using Minitab 17 statistical software. The analysis was conducted by comparing various distributions to determine the most suitable distribution based on the Goodness-of-Fit test results. The Normal distribution was initially applied as it is one of the most commonly used distributions, serving as a baseline to demonstrate that natural disaster events are relatively rare and do not follow this distribution. Subsequently, the Weibull, three-parameter Weibull, and Gamma distributions were employed to more accurately capture the actual characteristics and distributional shape of the natural disaster data.

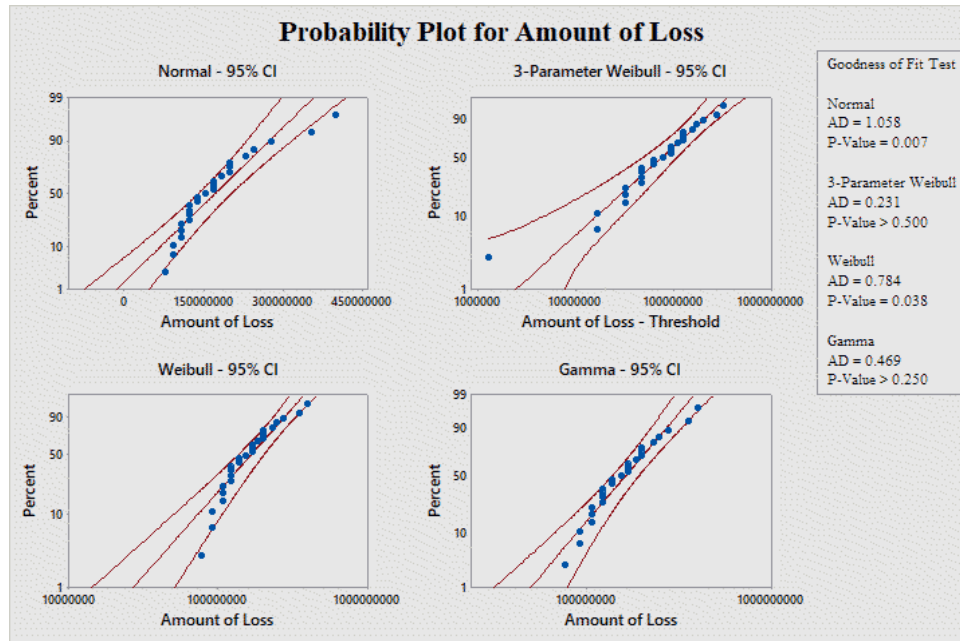


Figure 3. Goodness-of-Fit test result

Figure 3 shows that the normal and standard Weibull distributions are not suitable for the loss data because the p -value < 0.05 . However, the Gamma distribution showed a fairly good fit, but not as good as the 3-Parameters Weibull distribution which has more flexibility to capture data patterns, including the threshold nature of losses. Therefore, the 3-Parameters Weibull distribution is the best distribution to model this loss data reliably.

The test results from Minitab also provide estimates of the distribution parameters. Based on the distribution test results in Minitab, the parameters of the 3-Parameter Weibull distribution were estimated using the Maximum Likelihood Estimation (MLE) method. The estimated values are as follows, shape (k) = 1.22908, scale (λ) = 103,682,000, and threshold (γ) = 75,919,904.28. By using equation (3) and (4), the expected amount of loss due to floods and earthquakes is calculated as

$$E(X) = 75,919,904.28 + 103,682,000 \times \Gamma\left(1 + \frac{1}{1.22908}\right) = 1.7287 \times 10^8$$

while the variance is

$$Var(X) = (103,682,000)^2 \left[\Gamma\left(1 + \frac{2}{1.22908}\right) - \Gamma^2\left(1 + \frac{2}{1.22908}\right) \right] = 6.2894 \times 10^{15}$$

The obtained expectation and variances provide insight into the distribution of losses due to floods and earthquakes. Furthermore, this approach will support the implementation of a CRM designed to estimate total losses by combining event frequency and loss distribution.

3.4 Implementation of the Collective Risk Model

CRM is used to estimate the total loss caused by natural disasters in one year by combining two main components, namely the frequency of events based on the Poisson process and the amount of loss per event based on the 3-Parameters Weibull distribution. Based on the results of the previous analysis, the average annual floods and earthquakes frequency (λ) is 695.32 events per year, with a Poisson distribution assumed to model the pattern of events. On the other hand, the estimated loss per event follows a 3-Parameters Weibull distribution with an expected value of 172,869,711 and a variance of 6,289,422,912,759,202.

With these values, the following are the results of the calculation of the expectation of total natural disasters

$$E(S) = 695.32 \times 172,869,711 = 1.2020 \times 10^{11}$$

with the variance and standard deviation,

$$Var(S) = (695.32)(6.2894 \times 10^{15}) + (695.32)(1.7287 \times 10^{10})^2 = 2.5152 \times 10^{19}$$

$$STD = \sqrt{Var(S)} = \sqrt{2.5152 \times 10^{19}} = 501,518,3018.388$$

Thus, the results of the CRM implementation provide a comprehensive picture of the expectation and variance of total losses due to natural disasters. This analysis provides a solid basis for the next step in calculating the appropriate contribution for sharia insurance.

3.5 Contributions Calculation

The aggregate loss obtained in CRM will then be used to determine the total contribution of natural disaster insurance for floods and earthquakes. The total annual contribution is obtained based on the principle of expectation and standard deviation in equations (2) and (3). The loading factor used follows SEOJK No.6/SEOJK.05/2017 concerning the Determination of Premium Rates or Contributions in Property Insurance and Motor Vehicle Insurance Business Lines 2017. Contribution rate for dwelling house each for flood and earthquake from OJK Circular Letter Number 6/SEOJK.05/2017 [13] presented in Table 3 and Tabel 4.

Table 3. Contributions for flood insurance

Construction classes	Jakarta, Banten, West Java		Outside Jakarta, Banten, West Java	
	Criteria	Contribution (%)	Criteria	Contribution (%)
Zone 1 (Low)	Areas that have never experienced flooding or have experienced flooding, flood level \leq 30 cm	0.050% to 0.055%	Areas where the property to be insured has never experienced flooding before or has experienced flooding in the last 6 years or more.	0.045% to 0.05%
Zone 2 (Moderate)	Areas that have experienced flooding, 30cm < water level \leq 60 cm	Zone 1 Tariff + Factor Loading	The area where the property is to be insured has experienced flooding in the last 6 years.	0.050% to 0.055%
Zone 3 (High)	Areas that have experienced flooding, water level 60cm < water level \leq 100 cm	Zone 1 Tariff + Factor Loading	The area where the property to be insured has experienced flooding in the last 3 years	Zone 2 Tariff + Factor Loading
Zone 4 (Very High)	Areas that have experienced flooding, flood level > 100 cm	Zone 1 Tariff + Factor Loading	The area where the property to be insured has experienced flooding in the last 1 year	Zone 2 Tariff + Factor Loading

Table 4. Contributions for dwelling house because of earthquake

Construction classes	Contribution per mile (%)				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Steel, Wood, RC	0.76	0.79	1.04	1.35	1.60
Other	0.80	1.00	1.55	2.24	4.50

By taking the lowest rate, using the Python programming language, the contributions for earthquake insurance and flood insurance are presented in Table 5 and Table 6.

Table 5. Contributions for earthquake insurance

Construction classes		Contribution based on expected value (IDR)	Contribution based on standard deviation value (IDR)
Steel, Wood, RC	Zone 1	120,291,119,583.90169	120,203,579,299.49774
	Zone 2	120,294,725,576.9345	120,203,729,754.9883
	Zone 3	120,324,775,518.87457	120,204,983,550.74289
	Zone 4	120,362,037,446.88031	120,206,538,257.47859
	Zone 5	120,392,087,388.82042	120,207,792,053.23318
Other	Zone 1	120,295,927,574.61208	120,203,779,906.81847
	Zone 2	120,319,967,528.16415	120,204,782,943.42215
	Zone 3	120,386,077,400.43239	120,207,541,294.08226
	Zone 4	120,469,015,240.18707	120,211,001,770.36496
	Zone 5	120,740,666,715.32558	120,222,336,083.98651

Table 5 shows the contribution calculations for earthquake risk based on expected values and standard deviation values for dwelling house. This calculation shows that the total contribution using the expectation principle increases more significantly than the standard deviation principle. As a result, areas in higher risk zones face greater earthquake exposure and contribute more overall, especially for more vulnerable construction structures such as wood or others.

Table 6. Contributions for flood insurance

Location		Contribution based on expected value (IDR)	Contribution based on standard deviation value (IDR)
Jakarta, Banten, and West Java	Zone 1	120,205,777,748.7918	120,200,018,519.55469
	Zone 2	120,325,977,516.55219	120,205,033,702.57307
	Zone 3	120,446,177,284.3126	120,210,048,885.59146
	Zone 4	120,566,377,052.073	120,215,064,068.60985
Outside Jakarta, Banten and West Java	Zone 1	120,205,176,749.95299	120,199,993,443.63959
	Zone 2	120,325,376,517.71338	120,205,008,626.65797
	Zone 3	120,445,576,285.4738	120,210,023,809.67636
	Zone 4	120,565,776,053.23419	120,215,038,992.69476

Table 6 shows the result of contributions based on expected value and standard deviation value for sharia natural disaster insurance for floods. This calculation shows that the total contribution using the expectation principle increases significantly compared to the standard deviation principle. Regions inside Jakarta, Banten, and West Java are more prone to flooding, leading to higher total contributions. The zones within each region represent the area's flood vulnerability, categorized as follows: zone 1 (low risk), zone 2 (moderate risk), zone 3 (high risk), and zone 4 (very high risk). Consequently, areas in higher-risk zones face greater flood exposure and contribute more overall.

3.6 Model in Cash Flow

A mathematical table will be created based on the total contributions to outline the cash flow for CRM-based sharia natural disaster insurance. For the case illustration, it is assumed that the insured group resides in dwelling houses with steel, wood, RC construction under risk zone 1 area for earthquake and flood insurance. Using the standard deviation principle, the total annual contribution for this scenario is calculated as follows

$$\begin{aligned} \text{Contribution} &= \text{IDR } (120,203,579,299.49774 + 120,199,993,443.63959) \\ &= \text{IDR } 240,403,572,743.14. \end{aligned}$$

The risk management contract is structured using the *wakalah* and *tabarru'* principles. Under this arrangement, 90% of the total contributions collected from participants are allocated to the *tabarru'* fund (claim expenses, *retakaful*, and technical reserves as per company policies) while the remaining 10% serves as *ujrah* (fees). Investment management of the *tabarru'* fund operates under a *mudharabah* agreement, where 65% of the investment returns are reinvested into the *tabarru'* fund, and 35% are retained by the company. At the end of the year, any underwriting surplus, after covering all claims, is distributed as follows: 80% is added back to the *tabarru'* fund, 10% is allocated to the company, and 10% is shared with participants. The percentages applied across all sharia-compliant natural disaster insurance contracts are summarized in Table 7.

Table 7. Contribution proportions

Contribution		UW Surplus		Investment	
<i>Tabbaru'</i>	90%	<i>Tabbaru'</i>	80%	<i>Tabbaru'</i>	65%
<i>Ujrah</i>	10%	Company	10%	Company	35%
		Participants	10%		

Based on the calculation of contribution for the same scenario before, insurance company will store IDR 216,363,215,468.83 as a *tabbaru'* fund to cover the risk and IDR 24,040,357,274.31 as *ujrah*. *Tabbaru'* fund will later be managed by the company as a reserve to cover future claims, while also serving as part of that is expected to generate returns benefiting the participants, the company, and the further development of the *tabarru'* fund itself.

4. CONCLUSIONS

The development of a sharia insurance model for natural disasters using the CRM method shows that the contribution to earthquakes and floods has a similar pattern using both expectations and standard deviation, with the contribution value tending to be stable and increasing insignificantly as the probability of occurrence in a region increases. The insignificant increase in contribution value between risk zones was caused by the loading factor determined in determining contributions by the OJK which was also not very significant. The results of applying the model in cash flow calculations for the insured group resides in dwelling houses with

steel, wood, RC construction under risk zone 1 area for earthquake and flood insurance, indicate that the CRM method can be an effective and sustainable model for managing disaster risk in Indonesia while also reflecting sharia values, such as justice, mutual cooperation, and sustainability. This study does not account for natural disasters with extremely high severity that occur very rarely. Therefore, future research could focus on modeling rare major disaster events, such as those that occur once every 50 or 100 years.

5. ACKNOWLEDGMENTS

This research was conducted independently. We would like to express our gratitude to the BNPB and EM-DAT for providing the data needed in this study. Additionally, we sincerely thank the lecturers of Universitas Brawijaya for their invaluable teachings and guidance throughout our academic journey.

6. REFERENCES

- [1] Otoritas Jasa Keuangan, "Peraturan Otoritas Jasa Keuangan Republik Indonesia Nomor 20 Tahun 2023," Otoritas Jasa Keuangan, Indonesia, 2023.
- [2] World Population Review, "Muslim Population by Country 2024," 2024.
- [3] S. N. Nuhtay, M. Hamat, W. Z. W. Ismail and S. A. Salman, "Takaful (Islamic Insurance): Historical, Shari'ah and Operational Perspectives," *International Business Management*, vol. 9, no. 1, p. 65–69, 2015.
- [4] Badan Nasional Penanggulangan Bencana, "Data Bencana Indonesia," Badan Nasional Penanggulangan Bencana, Indonesia, 2024.
- [5] R. Cahyandari, D. Mayaningsih and Sukono, "A Design of Mathematical Modelling for the Mudharabah Scheme in Shariah Insurance," *Journal of Physics: Conference Series*, vol. 1090, no. 1, pp. 1-8, 2017.
- [6] R. Cahyandari, R. L. Sukono and Y. S. Perkasa, "The Hybrid Model Algorithm on Sharia Insurance," *Journal of Physics: Conference Series*, vol. 1090, no. 1, pp. 1-8, 2018.
- [7] Sukono, Kalfin, Riaman, S. Supian, H. Yuyun, S. Jumadil and M. Mustafa, "Determination of the Natural Disaster Insurance Premiums by Considering the Mitigation Fund Reserve Decisions: An Application of Collective Risk Model," *Growing Science*, vol. 11, no. 3, pp. 211-222, 2022.
- [8] H. M. Taylor and S. Karlin, *An introduction to stochastic modeling*, Academic Press, 2014.
- [9] R. E. Walpole and R. H. Myers, *Probability and Statistics for Engineers and Scientists*, Macmillan College, 2016.
- [10] L. Jantschi and S. D. Bolboaca, "Computation of Probability Associated with Anderson–Darling Statistic", *MPDI*, vol. 6, no. 88, p. 1-17, 2018.
- [11] S. A. Klugman, H. H. Panjer and G. E. Wilmot, *Loss Models: From Data to Decisions*, John Wiley & Sons, 2012.
- [12] Z. Djuric, "Collective risk model in non-life insurance," *Ekonomski Horizonti*, vol. 15, no. 2, pp. 163-172, 2013.
- [13] Otoritas Jasa Keuangan, "Surat Edaran Otoritas Jasa Keuangan Nomor 6/SEOJK.05/2017," Otoritas Jasa Keuangan, Indonesia, 2017.