IAJ
Indonesian Actuarial Journal
Persatuan Aktuaris Indonesia (PAI)

Vol. 01, No. 01, July (2025)
e-ISSN: xxxx-xxxx
https://ojs.aktuaris.or.id/iaj/index

Development of Economic Capital Using Value-at-Risk (VaR) for Catastrophe (Re)Insurance

Danar Handoyo[1*], Rahmalia Falah Anwar[2], Ruben Damanik[3], Rico Fernando Nainggolan[4]

[1,2,3,4]*PT Reasuransi MAIPARK, Jakarta, Indonesia*

*Corresponding email: danar.handoyo@maipark.com

Abstract

Effective risk management requires robust risk quantification by integrating a company's aggregate risk exposures. This approach strengthens risk awareness and informs mitigation strategies for stakeholders. This study explores economic capital as a framework for assessing risk-based capital requirements, specifically focusing on catastrophe risk in (re)insurance firms. The proposed risk quantification framework utilizes the Value-at-Risk (VaR) methodology to statistically estimate potential losses at predetermined confidence intervals. To address the inherent complexity of catastrophe risks, the model incorporates sophisticated distribution modeling and stochastic simulation techniques. These advanced analytical approaches are implemented through specialized catastrophe modeling platforms to optimize capital adequacy evaluations. This framework ensures financial resilience against extreme stress scenarios by implementing VaR at a predetermined threshold. The findings support management in optimizing capital allocation, risk controls, and mitigation strategies while balancing profitability and risk exposure.

Article History:
Received: 8 May 2025
First Revised: 12 May 2025
Accepted: 30 July 2025
Published: 31 July 2025

Keywords:
Risk quantification, economic capital, value at risk, catastrophe modelling, stress scenarios.

1. INTRODUCTION

The risk-based approach in capital allocation allows companies to allocate resources more efficiently according to the risk profile [1]. This study aims to analyze the risk-based capital requirements (which can be quantified) for five types of risks (out of nine risks) that have been defined by the Financial Services Authority (OJK) in the OJK Regulation [2] and OJK Circular Letter [3] including strategic risk, credit risk, market risk, insurance risk and operational risk. Through this approach, companies can determine capital adequacy in supporting the risks taken to deal with potential losses and comply with applicable regulations. This step is one of the efforts to improve the quality of risk management by building a measurable risk concept by prioritizing quantified measurements and focusing on preventing risks that cause insolvency [4]. Quantification per type of risk provides an overview of the strength of (re)insurance companies in meeting their obligations (solvent) in extreme risk events.

On this basis, risk measurement is needed to determine the capital requirements as risk support in anticipating losses due to extreme risks that will arise. Quantifying risks due to extreme losses is measured using the Value-at-Risk (VaR) method to estimate potential losses at a certain level of confidence [5]. Several complex distributions and simulations (Catastrophe Modeling) are adopted for risk analysis [6] in estimating appropriate capital requirements. VaR can be used to maintain the company's financial resilience to extreme pressures, support capital strategies, strengthen control and mitigation and risk diversification strategy options to balance profitability and risk optimally.

This study is specifically conducted for (re)insurance companies that cover catastrophe risks, especially earthquakes. Although the approach used in this study is general and can be applied to any (re)insurance company, fundamental differences exist in the aspects of insurance risk faced. In earthquake (re)insurance companies, risk volatility is much higher than in other business lines, so the approach to determining premium and claim reserve risks becomes more complex. These characteristics require an internal model that can capture high uncertainty in the frequency and severity of claims and consider factors such as spatial risk aggregation and correlation between events. Therefore, this study focuses on how internal models can be developed to provide more accurate estimates in calculating capital requirements for (re)insurance companies that focus on earthquake risk.

As part of the risk management process, risk quantification in the internal model is important in identifying and measuring the potential impact of various risks the company faces. This approach allows management to formulate more accurate data-based policies to increase the company resilience to uncertainty and ensure long-term operational continuity.

2. METHODS

The quantification method discussed here is the Value-at-Risk (VaR) statistical method. VaR is a statistical measure that measures the maximum potential financial loss that a company, portfolio or investment position may experience in a period with a certain level of confidence [7].

The study on Value-at-Risk (VaR)-based risk quantification supports the determination of capital derived of various risk components [5], as illustrated in the Figure 1, which presents a hierarchical classification of risks divided into three primary categories: Investment Risk (encompassing Market Risk and Credit Risk), Insurance Risk (comprising Life Risk and Non-life Risk), and Non-Financial Risk (including Operational Risk and Strategic Risk).

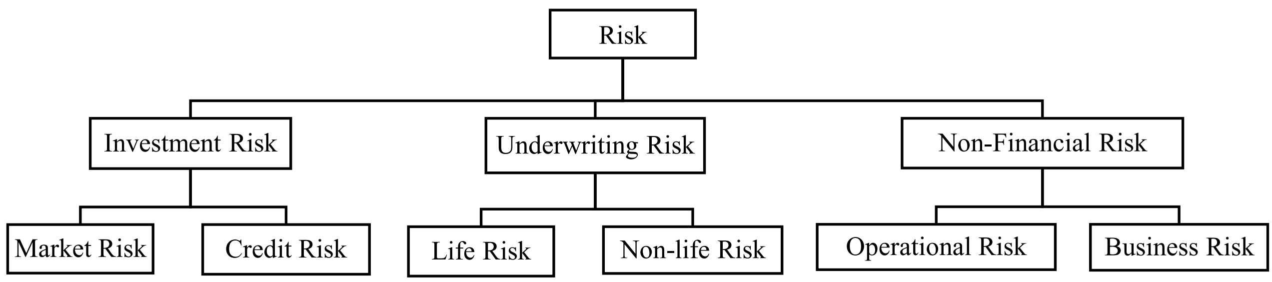

Figure 1. Risk categories (Modified from [8])

In practice in Indonesia, OJK has grouped nine types of risks, as stated in Circular Letter [3]. However, in this discussion, it can be concluded that there are six risks from reference [5] and OJK regulations [2],[3] that have the same meaning and can be quantified Table 1.

Table 1. Comparison of risk definitions

No	Risk Keywords [5]	Risk Keywords [2],[3]	Compliance
1	Underwriting risk: decreases in value due to differences or high claims.	Insurance risk: failure of a company to fulfill its obligations to the Policyholder, Insured, or Participant	Same substance
2	Market Risk: decrease in asset value due to changes in variables	Market Risk: resulting from overall changes in market conditions	Same substance
3	Credit Risk: the other party is unable to fulfill its obligations	failure of another party to fulfill its obligations to the Company	Same substance
4	Liquidity Risk: unexpected or high payments	Liquidity Risk: the inability of a company to meet its maturing obligations.	Same substance
5	Operational Risk: losses due to deficiencies in internal processes, people, systems or external events.	Operational Risk: inadequacy and/or dysfunction of internal processes, human error, system failure, and/or the presence of external events.	Same substance
6	Business Risk: losses due to changes in the competitive environment	Strategic Risk: failure to anticipate changes in the business environment	Same substance

This risk quantification based on the VaR statistical method is commonly called Economic Capital (EC). In this study, VaR expresses risk as the maximum loss that is likely not to be exceeded, except with probability $(1-\alpha)$, or VaR $(1-\alpha)$ is the maximum likely loss at confidence level α. In mathematically VaR can be written as:

$$VaR_{(1-\alpha)} = inf\{l\epsilon\mathbb{R}: P(L \leq l) \geq \alpha\} \quad (1)$$

Where α = tail probability and $(1-\alpha)$= confidence level. VaR can be measured using three main methods. The parametric (variance-covariance) approach assumes returns are (log-)normally distributed and calculates VaR as the mean minus a multiple of standard deviation based on the desired confidence level. The historical simulation approach uses actual past market data, sorting historical losses to find the empirical quantile at the chosen confidence level. The Monte Carlo simulation approach models the portfolio value by simulating many random scenarios based on estimated probability distributions, then extracts the quantile from these outcomes. Each method has trade-offs between simplicity, accuracy, and ability to capture extreme events. [5]

While, Economic Capital is the minimum capital reserve required to cover all unexpected losses that may arise from various risks faced by an insurance company within a certain time horizon, according to the level of confidence that is in line with the internal rating target to be achieved.

Other definitions have the same meaning as stated by [8], namely, economic capital is the minimum capital buffer needed to cover all unexpected losses that can be caused by the different risks to which the insurer is exposed within a certain time horizon and the confidence interval that corresponds to the internal rating ambition.

The basic formula used to calculate EC or losses from a type of risk will refer to the definition [5] above, namely:

$$EC = Unexpected\ Losses \quad (2)$$

where *Unexpected Losses* = $VaR_{(1-\alpha)} - expected\ Losses$.

The form of Formula (2) can be presented as:

$$EC = Worst\ case\ value\ (run\ off) - Best\ estimate\ value(run\ off) \tag{3}$$

where:

a. *Run-off* refers to the full settlement of all liabilities over time. *Run-off value* in this context is the total value of future cashflows needed to meet all liabilities as they emerge, until they disappear completely (i.e., run off).
b. *Worst case value (run off)* is the quantile of the present value of liability cashflows over the full run-off horizon, at a specified confidence level α. In this study worst case value is calculated using $VaR_{(1-\alpha)}$.
c. *Best estimate value* is the expected present value of all future liability cashflows under best estimate assumptions.

In general, for the context of a risk, EC can also be restated in the form of :

$$EC = VaR_{(1-\alpha)}(X_R) - E(X_R) \tag{4}$$

where:

$$VaR_{(1-\alpha)}(X_R) \text{ is } VaR_{(1-\alpha)} = \inf\{x_R \epsilon \mathbb{R}: P(X_R \leq x_R) \geq \alpha\} \tag{5}$$

$$E(X_R)\begin{cases} \sum_{x_R} x_R P(X_R = x_R), & discrete \\ \int_{-\infty}^{\infty} x_R f(x_R) dx_R, & continous \end{cases}. \tag{6}$$

This study will often use Formula (3), but further explanation will be provided if there are uses other than that. In this EC-based risk measurement, the causes of risk must be classified according to the existing risk categories (Figure 2). The risk categories in Figure 2 simplify the risk category structure in Figure 1 and are adjusted to the risk categories of the OJK.

Figure 2. Risk categories

Every risk has a cause; based on the definition of risk in OJK regulations, there are many possible causes of risk, for this reason, risk quantification/measurement is limited to risk causes that can be quantified (Table 2):

Table 2. Risk cause

No.	Risk Categories	Causes of Risk
1	Insurance	1. There is an actual claim that exceeds expectations (Premium Risk).
		2. The high deviation between the amount of claims paid and the claim estimate (best estimate) is due to fluctuations in the settlement of large claims (Claim Reserve Risk).
2	Market	Decrease in the value of investment assets due to changes in market variables such as interest rates, stock prices, exchange rates, real estate prices.
3	Credit	1. The bond issuer went bankrupt.
		2. The reinsurance panels went bankrupt.
4	Operational	Losses due to inadequate or failed internal processes, people, or systems or due to external events.
5	Strategic	Losses due to changes in the competitive environment or internal flexibility

With this understanding, Formula (3) is applied to each type/category of risk to obtain the EC for each risk.

$$EC_{Total} = EC_1 + EC_2 + EC_3 + EC_4 + EC_5 \quad (7)$$

where:

EC_1: Economic capital insurance risk
EC_2: Economic capital market risk
EC_3: Economic capital credit risk
EC_4: Economic capital operational risk
EC_5: Economic capital strategic risk

3. RESULT AND DISCUSSION

Based on the risk clasification described in Section 2 (Methods), the discussion of EC for each type of risk of loss refers to Table 2.

3.1 Insurance Risk

EC-based insurance risk quantification will be conducted for premium and claim reserve risks.

3.1.1 Insurance Risk – Premium Risk

Premium Risk is intrinsically linked to the premium pricing structure derived from existing loss/claim data. For earthquake catastrophe exposure, the Premium Risk calculation adapts Formula 1 as follows:

$$EC_{Premium\ Risk} = AEP\ Claim\ Loss\ Value\ \alpha\ \left(VaR_{(1-\alpha)}\right) - Net\ Premium\ Reserve \quad (8)$$

1. Aggregate Exceedance Probability (AEP) is a metric in catastrophe risk modeling that measures the cumulative probability that the total loss from all events in a period (e.g., one year) will exceed a certain threshold (Figure 3) [9]. The loss value with AEP α ($VaR_{(1-\alpha)}$) is a component of the worst-case value in EC Formula (3). In this case, the AEP α value is generated by catastrophe modeling that is simulated using computation and then utilizes the loss simulation results in the return period (RP) matrix [10].

2. Net premium reserves are a component of the expected loss value (best estimate), whereas premium reserves are an estimate of the expected loss.

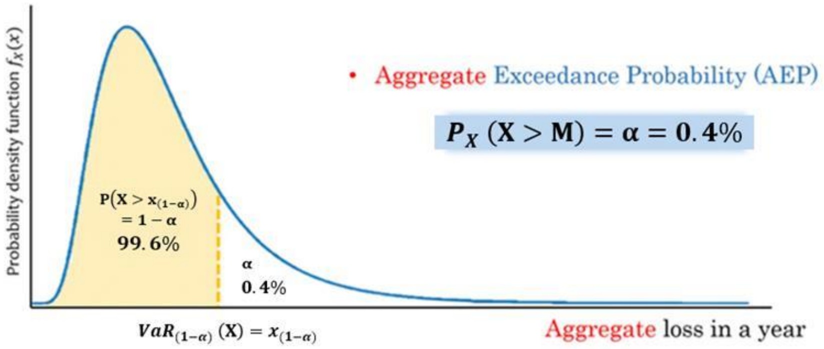

Figure 3. Aggregate annual loss distribution

The Figure 3 shows the probability density function $f_X(x)$ of aggregate loss in a year, illustrating the distribution of possible loss amounts. The vertical dashed line marks the Value at Risk at confidence level $(1-\alpha)$, defined mathematically as $VaR_{1-\alpha} = x_{1-\alpha}$. The shaded region to the left of $VaR_{1-\alpha}$represents the cumulative probability $1-\alpha$, meaning losses will not exceed this level with $(1-\alpha)$ confidence. The Aggregate Exceedance Probability (AEP) is exactly α, the probability that losses will exceed the VaR threshold. This VaR level $VaR_{1-\alpha}$ quantifies the worst loss that is only expected to be exceeded with probability α, providing a clear risk measure at confidence level $(1-\alpha)$.

3.1.2 Insurance Risk – Claim Reserve Risk

This study categorizes earthquake-related claims into three types of claim events (Table 3), based on the size of the ultimate claim: 'Attritional' for small claims less than or equal to threshold A, 'Significant' for medium claims between thresholds A and B, and 'Catastrophe' for large claims exceeding threshold B.

Table 3. Claim event types

Criteria	Event Types
Ultimate Claim ≤ A	*Attritional*
A < *Ultimate* Claim ≤ B	*Significant*
Ultimate Claim > B	*Catastrophe*

The level of occurrence (Value A and B) is obtained from Ultimate Loss Claims by considering factors such as the number of risks and the value of exposure affected and considering the year of occurrence and the applicable session limit [11]. Then, the resulting value is adjusted according to the Company's risk appetite. Based on this clasification, the calculation of claim reserves is adjusted to the characteristics of the large claims received, in this case:

1. Attritional claims are frequent insurance claims but with a relatively small value compared to significant claims or catastrophes. These claims are part of the risks estimated in daily insurance operations. The EC of attritional claims is calculated using the formula:

$$EC_{attritional\ Claims} = worst\ case\ run\ off\ -\ best\ estimate\ run\ off \quad (9)$$

   a. Worst case run off or worst case value in Formula (9) in attritional claims is calculated using the Mack Bootstrapping stochastic approach [12], [13] with Monte Carlo Simulation. This approach is taken with conservative considerations to see how claim reserves can vary in extreme scenarios. Determining the magnitude of extreme scenarios in catastrophe risk is very important because it can help companies understand and plan capitalization for the worst conditions. In this study's calculation of the Mack bootstrapping approach, R studio programming is used [14] with Monte Carlo repetition (e.g., n = 1,000).

b. The best estimate run-off or best estimate value in Formula (9) is calculated using the triangle method. This method utilizes historical claim development patterns to reflect future claim development patterns. The best estimate run-off taken is the mean value of the triangle method used, while the worst-case run-off is calculated with $VaR_{(1-\alpha)}$.

2. Significant & Catastrophic claim events are calculated using catastrophe internal modeling, namely MAIPARK Catastrophe Modeling (MCM), with the best estimate and worst case value results with $VaR_{(1-\alpha)}$. The EC formula used to calculate $EC_{significant\,\&\,catasthrope}$ is the same as Formula (9), but with the understanding:
   a. The worst-case value is the earthquake event modeling simulation value with $VaR_{(1-\alpha)}$.
   b. The best-estimated value is the simulation value of the expected earthquake loss modeling, which can be used using the average annual loss/AAL value approach.

3.1.3 Data Simulation

To provide a more applicable and clear understanding, the following is an example of calculating EC insurance risk in five years by applying Formula (8) for premium risk and Formula (9) for claim risk. The Table 4 shows the insurance risk calculation results over five years based on Premium and Claim components. Differences in results each year depend on the company's financial performance, especially the size of reserves and claim expenses in the current year. Negative values indicate that the company's reserves exceed the estimated losses, reflecting stronger protection against claim risks.

Table 4. Insurance risk result

In million IDR

Insurance risk	Year 1	Year 2	Year 3	Year 4	Year 5
Premium	4,446	-28,367	-27,259	-32,573	17,047
Claim	3,880	12,072	10,720	4,070	1,571
TOTAL	**8,326**	**-16,295**	**-16,539**	**-28,503**	**18,618**

3.2 Credit Risk

Credit risk is the risk of a decrease in value when a counterparty (bond issuer/reinsurance panel) cannot fulfill its obligations or when there is a change in the credit status of the counterparty. Identification carried out on the business process, the credit risk profile of the (re)insurance company that is the subject of the research comes from two sources, namely the investment portfolio in the form of bonds and the reinsurance panel. Based on this, EC-based credit risk from bonds and the reinsurance panel is quantifiable. For credit risk, EC is calculated based on the formula [5]:

$$\begin{aligned}\text{Economic Capital} &= \text{LGD} \times \text{EAD} \times \sqrt{\text{PD} \times (1-\text{PD})} - \text{LGD} \times \text{EAD} \times \text{PD} \\ &= \text{worst case value} - \text{best estimate value}\end{aligned} \tag{10}$$

Where for bond credit risk:

a. Probability of Default (PD): Chance of counterparty going bankrupt (%).
   The probability of Default (PD) value is obtained from the rating value published by each rating company according to the bonds owned by the company. Then, the PD value is $VaR_{(1-\alpha)}$ used as a reference from AM Best [15].
b. Loss-Given Default (LGD): Loss when a counterparty goes bankrupt, expressed as a percentage of outstanding (%).
   Loss-Given Default (LGD) value is obtained based on the experience of realization data when investors experience losses due to investing in a government bond that has defaulted. Due to this study's lack of

historical data, the LGD value approach for Government Bond Risk from Moody's Rating Default study [16] was used.

c. Exposure at Default (EAD): The nominal amount outstanding when the counterparty goes bankrupt. The Exposure at Default (EAD) value is obtained based on the sum of the principal value of the bond and the number of coupon payments until maturity.
d. The Best Estimate value is obtained using the formula:

$$PD \times LGD \ \times EAD \tag{11}$$

Meanwhile, for reinsurance panel risk, Formula (10) can be applied in the following context:

a. PD value can be obtained from the rating value published by each rating company according to the reinsurance panel used by the company. The PD value for company ratings can refer to AM Best, S&P, or others. PD value assessment, as an example, can be used [15] by selecting the range $VaR\ (1-\alpha)$ to be used according to the company's target.
b. The LGD value is obtained based on the realization data when a reinsurance panel experiences a payment default. When in reality there has never been a payment default, the LGD value is zero. However, with a conservative approach, so that LGD ≠0, then the future possibilities are considered, then the LGD value of the foreign panel as an approach can be estimated using a study conducted by the GIRO Working Group of the UK Institute of Actuaries [17] in the following Table 5:

Table 5. Reinsurance panel LGD value estimation [17]

AAA	AA+	AA	AA-	A+	A	A-	BBB+	BBB	BBB-	NR
0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.8

Exposure at Default (EAD) Value. The EAD value is obtained based on the potential claim recovery. Claim recovery is estimated using a cat model based on per panel per layer in excess of the loss reinsurance program. The EAD value is selected based on the estimated claim value with $VaR_{(1-\alpha)}$. The Best Estimate Loss value is obtained using the Formula (11). The result of credit risk calculation over five years shown in the Table 6, split between bond risk and reinsurance panel risk. The reinsurance panel consistently contributes the largest share of credit risk compared to bonds, reflecting greater exposure to counterparties in reinsurance agreements. Variations across years indicate changes in exposure levels and credit quality assumptions, highlighting the importance of regular monitoring and updating of credit risk assessments.

Table 6. Credit risk result

In million IDR

Credit risk	Year 1	Year 2	Year 3	Year 4	Year 5
Bond	31	39	136	135	824
Reinsurance Panel	83,124	49,410	40,984	37,242	27,496
TOTAL	**83,155**	**49,449**	**41,120**	**37,377**	**28,320**

3.3 Market Risk

Market risk is the potential for a decline in the value of assets due to fluctuations in market variables such as interest rates, stock prices, exchange rates, property prices, and the like [18]. This risk is classified based on the type of market variable affected, depending on the investment portfolio structure of the (re)insurance company. General categories of market risk include [5]:

a. Interest rate risk: The risk of a decline in value due to changes in interest rates. The balance between assets and liabilities (cash flow from claim reserves) is very important because it is directly affected by interest rates.
b. Equity risk: The risk of a decline in value due to stock price fluctuations.

c. Exchange rate risk: The risk resulting from changes in foreign exchange rates (also known as Foreign Exchange risk).
d. Inflation risk: The risk that changes in inflation expectations affect the real value of assets and liabilities.
e. Property risk: The risk arising from a decline in the value of real estate assets.
f. Private equity risk is the risk of a decline in value due to dynamics in non-public equity markets. Although it is included in equity risk, its specific nature makes it a separate category.
g. Credit spread risk: The risk of a decline in value due to changes in the credit spread is the difference between the yields of corporate and government bonds. Unlike credit risk, this risk reflects general market sentiment, not the condition of a particular issuing entity.

The method used to calculate economic capital at market risk is the replicating portfolio method. This method constructs an imaginary investment portfolio replicating insurance liabilities' cash flows, especially those derived from technical reserves based on claims development (excluding premium or direct claims). This portfolio can consist of stocks, bonds, derivatives, or options. Thus, two portfolios were analyzed: the actual asset and the imaginary replicated portfolios. Next, simulations are performed using statistical models to construct scenarios of market variables (e.g., interest rates) based on the current market structure. This process is repeated n times (e.g., 100,000) to generate a distribution of values.

The simulation is applied to both portfolios. The difference in value between the actual portfolio and the replicated portfolio reflects the capital requirement. The distribution of the simulation results allows the estimation of risk values such as VaR and best estimate. This process is visually illustrated in Figure 5, which illustrates the market risk modeling workflow, from model creation and scenario simulation to analysis of its impact on the balance sheet and capital.

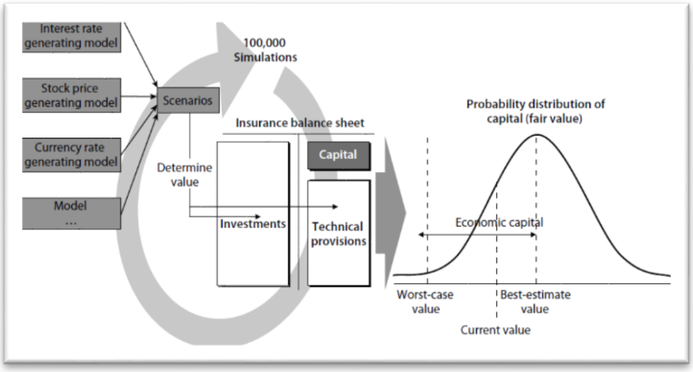

Figure 4. Economic Capital for Market Risk [5]

Calculating economic capital for market risk based on the portfolio replication method is more suitable for life (re)insurance, while the Economic Scenario Generator (ESG) tool (stochastic) or the stress test approach (deterministic) is more suitable for general (re)insurance.

Calculating economic capital for market risk using stress test calculation can focus on the financial crisis scenario that occurs simultaneously/simultaneously so that it puts extreme pressure on the company's investment assets. This crisis scenario will impact the financial market by affecting interest rates and other investments such as stocks, property, currency values, and inflation. So the value of economic capital market risk is the difference between the actual value and the stress test result value of each component used as a stress test indicator. For example, the data below capturing the impact of the stressed scenario on each market risk component (Table 7) shows the impact of market risk over five years, split between currency fluctuations and investment valuations. The differences in results across years arise from varying stress test scenarios that reflect different market conditions each year. This approach allows the scenarios to be adjusted to match the prevailing market environment, making the outcomes more realistic and relevant for risk assessment.

Table 7. Market risk result

In million IDR

Market risk	Year 1	Year 2	Year 3	Year 4	Year 5
Currency impact	1,093	1,664	1,229	3,939	97,700
Investment impact	28,551	34,942	89,275	90,169	137,438
TOTAL	**29,644**	**36,606**	**90,504**	**94,108**	**235,138**

3.4 Operational Risk

The calculation of EC for operational risk must consider the potential for operational failure scenarios that cause reputational damage and financial risk. For this reason, because operational failure realization data is sometimes very difficult to provide in sufficient quantities, the approach can use references from expert opinions and opinions of senior company managers or risk owners. In addition, other options may be possible, such as referring to other countries to determine the minimum capital required for operational risk. For example, referring to the Australian Prudential Regulation Authority (APRA) [19] in the calculation of operational risk determined according to Prudential Standard GPS 118 Capital Adequacy: Operational Risk Charge (GPS 118) [20], the calculation of operational risk for insurance is calculated based on the formula:

$$OR = 3\% \times \left(max(GP1, NL) + max(0, |GP1 - GP0| - 0{,}2 \times GP0)\right) \tag{12}$$

where:

OR : Operational risk charge.

GP1 : Gross premiums (including reinsurance) for the 12 months ended on the reporting date.

GP0 : Gross premiums (including reinsurance) for the 12 months ending on the 12th day of the previous month to the reporting date.

NL : Central estimate of insurance liabilities (net of reinsurance) determined by Prudential Standard Assessment of Insurance Liabilities GPS 340 (GPS 340), at the reporting date (net technical reserves).

3.5 Strategic Risk

Strategic risk reflects the potential for losses due to changes in the external environment (competitors, customers, policies) or limitations in the company's internal responses. This risk is measured using three main approaches [5]:

1. Company analogy.
   The company's activities are assumed to be similar to those of a non-financial company. For example, suppose 40% of the activities resemble a financial services provider (with a capital-to-operating expense ratio of 45%), and 60% resemble an information processing company (70%). In that case, the estimated economic capital is 60% of fixed operating expenses. If fixed costs are Rp300 million, then the capital required is Rp180 million.
2. Income volatility.
   A statistical approach that measures the deviation of historical returns, corrected for other risk factors. It assumes a normal distribution; capital is calculated as the difference between expected and extreme returns (e.g. 99.6% VaR). The advantage is statistical consistency, but separating the influence of strategy risk from other risks is challenging.
3. Scenario analysis.
   Management identifies key strategic threats and estimates their financial impact. Each scenario is assessed in terms of probability, impact, and mitigation options. While subjective, this approach is useful in supporting strategic decision making and risk management integration.

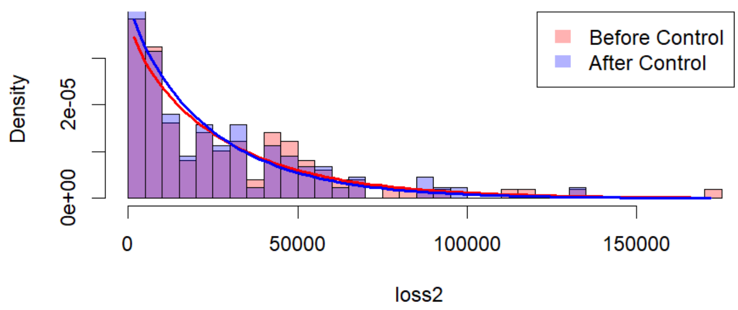

Figure 5. Weibull fit distribution

Based on data availability, strategic risk is calculated based on the deviation between target and realization of monthly premium income. Losses are calculated as the negative difference between target and realization, then the fitting process is continued to a distribution. The results of the appropriate distribution are then used in determining the EC estimate for the VaR value that matches the company's target. To illustrate this process the Figure 5 provides an example of the fitted Weibull distribution for loss data before and after applying control. The overlaid histograms show that the after-control data is more concentrated at lower loss levels, indicating a reduction in extreme deviations from target premiums. The fitted Weibull curves confirm this shift through a lower scale parameter, while maintaining a similar shape parameter, suggesting that the underlying pattern of strategic risk remains consistent. This result demonstrates that the control measures effectively reduce average loss severity without fundamentally changing the distributional form of the risk, supporting more robust and reliable Economic Capital estimation.

3.6 Diversification

Diversification occurs when different activities complement each other, both in terms of profit and risk [5]. For example, life insurance and pension products can balance each other out. In the case of a major disaster, even though life expectancy decreases (impacting life insurance), rising interest rates actually benefit pension funds. This shows how the risk of one line can be covered by the profit in another line.

The diversification effect is measured using a correlation factor. A correlation value of 1 means that two events always occur together. In the context of economic capital, diversification is divided into three types [5]:

1. Diversification within one risk category in one business unit, such as:
   Non-life insurance claims can be spread across multiple products, such as property and vehicles, because the risks do not occur simultaneously. In life units: placing investments across multiple instruments prevents the entire portfolio from experiencing a simultaneous decline.
2. Diversification between business units within one risk category, for example by opening additional business units so that claims are not concentrated in one unit.
3. Diversification between risk categories, namely the interaction between insurance, market, credit, operational and strategic risks.

This study discusses the diversification calculations carried out on the third type using the correlation approach between risks, referring to the Solvency II Guidelines from EIOPA [21].

Calculating diversification is a factor in reducing total capital requirements, considering the interrelationships between risks. This process involves estimating economic capital, each risk (standalone), and the correlation matrix between risks. To calculate the diversification factor, we use all of the risks that have been calculated above to derive the correlation factors, which are then used to compute the diversification benefit across these risks. The diversification formula is [22]:

$$Diversified\ EC = \sqrt{\begin{pmatrix} EC_1 \\ EC_2 \\ EC_3 \\ EC_4 \\ EC_5 \end{pmatrix}^T \begin{pmatrix} 1 & \rho_{1,2} & \dots & \dots & \rho_{1,5} \\ \rho_{2,1} & 1 & \dots & \dots & \rho_{2,5} \\ \rho_{3,1} & \dots & 1 & \dots & \rho_{3,5} \\ \rho_{4,1} & \dots & \dots & 1 & \dots \\ \rho_{5,1} & \dots & \dots & \dots & 1 \end{pmatrix} \begin{pmatrix} EC_1 \\ EC_2 \\ EC_3 \\ EC_4 \\ EC_5 \end{pmatrix}} \tag{13}$$

where:

$Subscript$:
1 = Insurance Risk
2 = Market Risk
3 = Credit Risk
4 = Operational Risk
5 = Strategic Risk
ρ = Correlation factor

The diversification factor is obtained using the formula:

$$Diversification\ Factor = \frac{EC\ (Total) - Diversified\ EC}{EC\ (Total)} \tag{14}$$

Factor values approaching 1 indicate large diversification benefits, which means it can be a significant reduction in the economic capital requirements in Formula (3). So the final formula (taking diversification into account) is:

$$EC_{Company} = EC_{Total} - (Diversification\ Factor \times EC_{Total}) \tag{15}$$

3.7 Study Case

To clarify the explanation above, the following part is an example of a calculation from a company's actual data. The purpose is to find out the company's EC needs in the 5th year by knowing the company's economic capital data for each type of risk over five years (Table 8). This study case serves as an application of the methods described in Sections 3.1 to 3.6.

Table 8. Study case of EC over 5 years

In million IDR

Economic Capital	Year 1	Year 2	Year 3	Year 4	Year 5
Market risk	29,644	36,606	90,504	94,108	47,999
Credit risk	83,155	49,449	41,120	37,377	28,320
Insurance risk	8,326	-16,295	-16,539	-28,503	18,618
Strategic risk	98,061	93,096	113,201	104,100	104,115
Operational risk	8,728	9,097	10,023	10,804	7,476
$\boldsymbol{EC_{Total}}$	**227,914**	**171,953**	**238,309**	**217,886**	**206,528**

By using simple mathematical correlation to calculate the matrix correlation, the diversified EC from the Formula (13) is:

$$Diversified\ EC = \sqrt{\begin{pmatrix} 47{,}999 \\ 28{,}320 \\ 18{,}618 \\ 104{,}115 \\ 7{,}476 \end{pmatrix}^T \begin{pmatrix} 1 & -0.56 & -0.66 & 0.78 & 0.76 \\ -0.56 & 1 & 0.19 & -0.46 & -0.05 \\ -0.66 & 0.19 & 1 & -0.13 & -0.93 \\ 0.78 & -0.46 & -0.13 & 1 & 0.3 \\ 0.76 & -0.05 & -0.93 & 0.3 & 1 \end{pmatrix} \begin{pmatrix} 47{,}999 \\ 28{,}320 \\ 18{,}618 \\ 104{,}115 \\ 7{,}476 \end{pmatrix}}$$

$$Diversified\ EC = 131{,}056\ (in\ million\ IDR)$$

And we have the Diversification factor from Formula (14) is 36.54%. To find the company's EC for the 5th year after apllying the Formula (15) is:

$$EC_{Company} = 206{,}528 - 131{,}056 = 75{,}472\ (in\ million\ IDR)$$

4. CONCLUSIONS

This study is essential for ensuring the capital adequacy of (re)insurance companies that specialized in catasthrope as they manage credit, strategic, market, insurance, and operational risks. The result of this study provides a quantified risk metric at a chosen confidence level (VaR). This research has produces a standalone total EC of approximately 206 in billion IDR in the 5th year, which applying a diversification benefit of 36.54%, underscoring the significant risk mitigation achievable through risks diversification. Additionally, the reliability of these results depends on the quality and sufficiency of historical data, expert judgment inputs, and model calibration, which remain key constraints in practice. Future research should consider integrating alternative risk measures like Tail-VaR or stress-testing frameworks that better capture extreme scenarios, and assess model performance over time to determine whether VaR estimates remain accurate under changing market and exposure conditions, and refine the approach to make the model more practical and aligned with the organization's specific context and decision-making needs.

5. ACKNOWLEDGMENTS

The authors want to express grateful thank to Kocu Andre Hutagalung, Reza Andre Nasution, Sunarso, Dumaria Tampubolon and Dodi Susanto for their constructive and positive comment in this research. This study was supported by PT Reasuransi MAIPARK Indonesia, Jakarta.

6. REFERENCES

[1] Ai, J., Brockett, P. L., Cooper, W. W., & Golden, L. L. (2012). Enterprise Risk Management Through Strategic Allocation of Capital. *The Journal of Risk and Insurance*, *79*(1), 29–55. http://www.jstor.org/stable/41350678

[2] Peraturan Otoritas Jasa Keuangan Nomor Nomor 44 /POJK.05/2020 tentang Penerapan Manajemen Risiko Bagi Lembaga Jasa Keuangan Nonbank.

[3] Surat Edaran Otoritas Jasa Keuangan Nomor 8/SEOJK.05/2021 tentang Penerapan Manajemen Risiko bagi Perusahaan Asuransi, Perusahaan Asuransi Syariah, Perusahaan Reasuransi, dan Perusahaan Reasuransi Syariah.

[4] Azhar, A.K., Gan, V.B., Abdullah, W., & Zainuddin, H. (2015). On the Fractal Geometry of the Balance Sheet and the Fractal Index of Insolvency Risk. arXiv: Risk Management.

[5] Doff, R. (2011). Risk Management for Insurers: Risk Control, Economic Capital and Solvency II. United Kingdom: Incisive Media Investments Ltd.

[6] Damanik, R., Gunawan, E., Widiyantoro, S., Supendi, P., Atmaja, F. W., Ardianto, Husni, Y. M., Zulfakriza, and Sahara, D. P. (2023): New assessment of the probabilistic seismic hazard analysis for the greater Jakarta area, Indonesia, Geomatics, Natural Hazards and Risk, 14(1), 2202805.

[7] Jorion, P. (2007). Value at Risk: The New Benchmark for Managing Financial Risk: McGraw-Hill.

[8] Burns, R.L. (2023). Economic Capital The Assessment of Capital Adequacy. USA: Federal Deposit Insurance Corporation.

[9] Humphreys, N. (2021). Casualty Actuarial Society E-Forum, Winter 2021: Exceedance Probability in Catastrophe Modeling.

[10] Mitchell-Wallace, K., Jones, M., Hillier, J., Foote, M. (2017). Natural Catastrophe Risk Management and Modelling: A Practitioner's Guide. John Wiley & Sons Ltd.

[11] MAIPARK. (2017). Laporan Aktuaris Tahunan PT Reasuransi MAIPARK Indonesia Per 31 Desember 2017.

[12] Mack, Thomas. (1993). Distribution-Free Calculation Of The Standard Error Of Chain Ladder Reserve Estimates. *Astin Bulletin*, Vol. 23.

[13] Lowe, Julian. (1994). A Practical Guide To Measuring Reserve Variability Using: Bootstrapping;, Operational Time And A Distribution-Free Approach. General Insurance Convention.

[14] Buzz, A. (2017). BootstrapMack [Version 2017]. [Software]. [https://github.com/ArnaudBu/ReservingLad/]

[15] Jakobsen, M., (et al). 2022. Best's Methodology and Criteria, Understanding Global BCAR.

[16] Moody's Investor Service. (2022). Annual Default Study: After A Sharp Decline In 2021, Defaults Will Rise Modestly This Year.

[17] Britt, S. Krvavych, Y. (2009). Reinsurance Credit Risk Modelling: DFA Approach.

[18] Corelli, A. (2024). Market Risk, Understanding Financial Risk Management, Third Edition. Emerald Publishing Limited, Leeds, pp. 173-194.

[19] APRA. (2025). APRA Prudential Handbook. Diakses 12/12/2023 dari https://handbook.apra.gov.au/

[20] APRA. (2023, 1 Juli). GPS 118 Capital Adequacy: Operational Risk Charge. Diakses pada 12/12/2023, dari https://handbook.apra.gov.au/standard/gps-118#detail

[21] EIOPA. (2024). Study on Diversification in Internal Models. Public Report.

[22] Larsson, H. (2009). Inter-Risk Correlation within Economic Capital.