Supply Chain Strategy for Measuring Risk through Capital Allocation: An Application of Incremental and Activity Based Methods

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***Abstract*— the insurance company needs a good strategy for ensuring its existence and ability to survive in the insurance world competition with reducing the chance of loss risk. Thus, this paper is written to investigate the capital allocation for measuring risk via a mathematical approach namely Value-at-Risk (VaR) so that insurance companies can find out the magnitude of the worst risks that may occur. The amount of capital allocation analysed using Incremental and Activity-Based Methods. Also, this study uses the simulation data of random numbers obtained from the calculation of premium and claims for insurance programs. The results of the analysis showed that a positive value for the diversification process. It indicates that the insurance company has met its obligations. The total risk of all portfolio returns is IDR19,013,620,433.00. Using the capital allocation analysis, this study found that the Portfolio 1 as much as IDR4,938,935,765.00, Portfolio 2 is IDR4,787,472,037.00, and Portfolio 3 as big as IDR5,544,572,898.00.**

***Keywords*—** *Premium, Insurance program, Value-at-Risk, Activity and Incremental-Based Methods, Solvency Capital Requirements.*

1. Introduction

The insurance company is developed to stabilize business conditions from various risks that occur so that the company can continue to expand its business without worrying. The main goal of insurance is to uphold a sense of solidarity among parties involved, shared responsibility in protecting individual or groups against unexpected risk [1]. Insurance is very closely related to risk. Risk is the magnitude of the deviation between the expected return with the actual return [2]-[3]. Insurance companies to survive must be able to meet their obligations. For overcoming this, the insurance company not only calculates the risk value from the value of the premium but also must calculate the capital adequacy, so we need a method to solve it, and the technique is called solvency [4]-[5]. There are two types of Solvency, namely Solvency I which depends only on premiums or claims, different from Solvency II which is more complicated. Solvency II consists of three main pillars, but this study only uses pillar 1. Pillar 1 is the financial source of a company to survive or be solvent. In pillar 1 there is a method called Solvency Capital Requirements (SCR) [6] - [7].

Insurance solvency is related to several components that are indispensable for managing losses and avoiding bankruptcy. One of them is the underwriting performance of the company. Several insurance companies can maintain the level of solvency while maintaining underwriting performance [6]. Referring to Balog research [3], the results of company underwriting have a significant positive effect on the level of solvency of insurance companies. So the increase in underwriting results will have a positive impact on solvency seen from the SCR value. The problem that often arises about the level of solvency is the inadequacy of capital. It is the focus of attention of the Financial Services Authority because until now,

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these problems have become obstacles in the development of insurance companies [8]. Research by Haan and Kakes [9] who observed the solvency of insurance companies in the Netherlands stated that the proportion of shares positively affected the solvency of insurance companies. Referring to the research of Haan and Kakes [9], the large number of people who use insurance services can cause over claims which is one of the risks for insurance companies. The risk of loss can identify by determining the Value-at-Risk (VaR) value in the insurance claim big data [10]-[11].

Solvency Capital Requirements (SCR) are widely used in the financial sector; this has resulted in many different approaches. So that makes the Solvency Capital Requirements equation also differs. Therefore, by listening to the description above, in this study, the standard form of the Solvency Capital Requirements (SCR) will be used. The aim is to determine the amount of Value-at-Risk (VaR), so those insurance companies can find out the magnitude of the worst risks that may occur, so that it can be taken into consideration in determining the amount of capital that must be allocated to diversify the formation of investment portfolios.

2. Methodology

In this section, a brief description of the mathematical models used in this study is discussed.

2.1. Indicator Equation

In insurance companies, a mathematical model is needed to solve some of the existing problems. According to Balog [13] and Braun et al. [12], suppose that $N = \{1, 2, 3, \ldots, n\}$ $N = \{1, 2, 3, \ldots, n\}$ is a set of positive consumer portfolios. Portfolio *i* ($i = 1, 2, 3, \ldots, n$ $i = 1, 2, 3, \ldots, n$) must pay an amount of premium $p_i \in R^+$ $p_i \in R^+$ to the insurance company. Portfolio claim *i* is given by $X_i X_i$ where $X_i X_i$ is a collection of real random variables $\Gamma\Gamma$ which are often called probability space $(\Omega, \mathcal{F}, \mathbb{P})$ $(\Omega, \mathcal{F}, \mathbb{P})$. Assume all claims are independent and have limited average value. Then state the distribution function of $\mathbb{P}[X_i \leq x_i]$ $\mathbb{P}[X_i \leq x_i]$ $X_i X_i$ by $F_{Xi}(x) F_{Xi}(x)$.

The total claim of an insurance company as follows:

$$X = \sum_{i=1}^{n} X_i X = \sum_{i=1}^{n} X_i \tag{1}$$

and the total premium is determined by:

$$P = \sum_{i=1}^{n} P_i P = \sum_{i=1}^{n} P_i \tag{2}$$

Suppose U is capital owned by an insurance company and $X_i\,; i \in N X_i\,; i \in N$ as a realization of individual claims. In the simple model, assume that:

$$\sum_{i=1}^{n} X_i \leq U + \sum_{i=1}^{n} P_i \quad \sum_{i=1}^{n} X_i \leq U + \sum_{i=1}^{n} P_i \tag{3}$$

Equation (3) is an indicator that shows the continuity of insurance companies. If there is a situation where the total claim amount is higher than the total premium and capital, so it can be said that the insurance company can no longer afford to pay the claim amount from all agreed portfolios [3].

2.2. Portfolio

Portfolios are used as a strategy to maximize returns or minimize risk. To get the optimal portfolio done through the weighting composition in the allocation of capital. Portfolios that provide a high average return value, with low risk, are the best choices [4], [11]. Sustainability of an insurance company depends on the difference between the total amount of premiums and the total amount of the claims of all portfolios simultaneously, so that when the total number of claims is greater than the sum of the total premium, the company will suffer a loss [13].

2.2.1. *Return of insurance company*

The return is a significant indicator for determining whether a company will experience profits or losses. If we let P is the total premium, U is the capital owned by an insurance company, S is the total claims, then to determine the return is:

$$X = (P + U) - SX = (P + U) - S \quad (4)$$

2.2.1. *Average and return risk*

If supposed the sample of return size m with $x_1, x_2, \dots, x_m x_1, x_2, \dots, x_m$, then the average $\mu\mu$ can be calculated using:

$$\mu = \frac{\sum_{i=1}^{m} x_i}{m} \mu = \frac{\sum_{i=1}^{m} x_i}{m} \quad (5)$$

And risk as variance $\sigma^2 \sigma^2$ or standard deviation σ σ can be calculated using [13]:

$$\sigma^2 = \frac{\sum_{i=1}^{m}(x_i-\mu)^2}{m-1} \sigma^2 = \frac{\sum_{i=1}^{m}(x_i-\mu)^2}{m-1} \text{ or}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{m}(x_i-\mu)^2}{m-1}} \sigma = \sqrt{\frac{\sum_{i=1}^{m}(x_i-\mu)^2}{m-1}} \quad (6)$$

Suppose $X_i X_i$ where $i = 1, 2, \dots, n i = 1, 2, \dots, n$ is portfolio return ii that have average $\mu_i \mu_i$, then combined portfolio average $\mu_c \mu_c$ is calculated using:

$$\mu_c = \sum_{i=1}^{n} \mu_i \mu_c = \sum_{i=1}^{n} \mu_i. \quad (7)$$

If the combined variance is expressed by $\sigma_c^2 \sigma_c^2$, it can be determined using equations [13]:

$$\sigma_c^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} Cov(X_i, X_j)$$

$$\sigma_c^2 = \sum_{i=1}^{n} \sum_{j=1}^{n} Cov(X_i, X_j). \quad (8)$$

2.2.1. *Correlation*

Correlation is a statistical technique used to measure the strength of the relationship between two variables, and also to determine the form of the relationship between the two variables, quantitatively. The strength of the relationship between the two variables referred to here is close, weak, or not close, while the form of the relationship is whether the correlation is linearly positive or linearly negative. The equations used to calculate the correlation between variables *X* and *Y* with their values are x_i and x_i y_i y_i; $i = 1, 2, \dots, m$, can be stated as $i = 1, 2, \dots, m$ [13]-[14]:

$$r_{xy} = \frac{m\sum_{i=1}^{m} x_i y_i - (\sum_{i=1}^{m} x_i)(\sum_{i=1}^{m} y_i)}{\sqrt{\{m\sum_{i=1}^{m} x_i^2 - (\sum_{i=1}^{m} x_i)^2\}\{m\sum_{i=1}^{m} y_i^2 - (\sum_{i=1}^{m} y_i)^2\}}} \quad (9)$$

$$r_{xy} = \frac{m\sum_{i=1}^{m} x_i y_i - (\sum_{i=1}^{m} x_i)(\sum_{i=1}^{m} y_i)}{\sqrt{\{m\sum_{i=1}^{m} x_i^2 - (\sum_{i=1}^{m} x_i)^2\}\{m\sum_{i=1}^{m} y_i^2 - (\sum_{i=1}^{m} y_i)^2\}}}$$

2.3. *Value-at-Risk*

Value-at-Risk (VaR) is a measure that can be used to assess the risk of the worst losses that might occur to insurance companies. In VaR the probability of loss is calculated from the worst possible loss than a predetermined presentation. Value-at-Risk (VaR) is a measure of risk which is interpreted as a risk threshold value of claim $X_i X_i$ so that the possibility of exceeding this threshold value is less than or equal to a predetermined level $(1-\alpha)(1-\alpha)$. Formally, Value-at-Risk (VaR) is defined as follows.

If we let $\alpha \in (0,1) \alpha \in (0,1)$ and $X_i X_i$ random variables, then:

$$VaR_\alpha(X_i) = \inf\{x \in \mathbb{R} : F_{X_i}(x) \le \alpha\} \quad (10)$$

$$VaR_\alpha(X_i) = \inf\{x \in \mathbb{R} : F_{X_i}(x) \le \alpha\}$$

where $F_{X_i}(x) F_{X_i}(x)$, is a probability distribution function of the random variable $X_i X_i$ [2], [10].

2.4. *Solvency II*

This section discusses solvency II. Solvency II is based on three main pillars, namely: (1). quantitative requirements; (2). requirements for governance and risk management of the guarantor; and (3). focus on requirements that are open and transparent. The first pillar of Solvency II, is very important in this study because it covers quantitative aspects [6], [16].

2.4.1. *Pillar 1*

Pillar 1 is a financial source that must be owned by an insurance company to be considered solvent. Financial resources in solvency II are referred to as Solvency Capital Requirements (SCR) [17]. Consider that for each risk *i*, $i = 1, 2, \dots, n$, contained in a portfolio with the $i = 1, 2, \dots, n$ number of claims $X_i X_i$. Then, take a measure of risk $\rho(X_i)$ $\rho(X_i)$ so that portfolio *i* can be considered *solvent*. The level of $SCR_i SCR_i$ of risk *i* is defined as follows [5]:

$$SCR_i = \rho(X_i) SCR_i = \rho(X_i) \quad (11)$$

Consider that the sum of all risks as an aggregate for all claims in the portfolio. Take a risk $\rho(\sum_{i=1}^{n} X_i)$ $\rho(\sum_{i=1}^{n} X_i)$ so that the sum of all portfolios can be considered solvent. Then SCR_N SCR_N for all n risks is defined as follows:

$$SCR_N = \rho(\textstyle\sum_{i=1}^{n} X_i), \text{with } N = \{1, 2, 3, \dots, n\}$$
$$SCR_N = \rho(\textstyle\sum_{i=1}^{n} X_i), \text{with } N = \{1, 2, 3, \dots, n\} \quad (12)$$

So that the SCR level for each insurance company with n different risks, consists [6]:

$$SCR_i = \rho(X_i), \forall i \in N SCR_i = \rho(X_i), \forall i \in N \quad \text{and}$$
$$SCR_N = \rho(\textstyle\sum_{i=1}^{n} X_i) SCR_N = \rho(\textstyle\sum_{i=1}^{n} X_i) \quad (13)$$

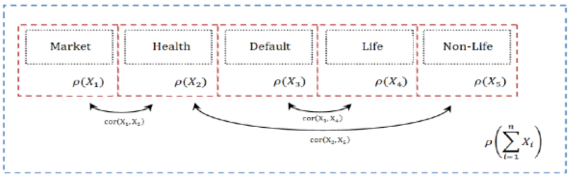

Figure 1. Solvency requirements level

A general chart of the solvency requirements level is shown in figure 1. The red part indicates SCR_i SCR_i of individual risk and the blue one includes SCR of total risk. Therefore, the right definition for $SCR_i SCR_i$ at risk *i* is that Solvency Capital Requirements (SCR) are the level of capital that must be held, at least the company has sufficient resources to meet its obligations within 12 months with a probability of at least 99.5% [8].

Therefore, it can be said that the definition of Solvency Capital Requirements (SCR) has to do with Value-at-Risk (VaR) [10]. Substitute the risk measures $\rho(X_i)$ and $\rho(\sum_{i=1}^{n} X_i)$ $\rho(X_i)$ and $\rho(\sum_{i=1}^{n} X_i)$ into:

$$SCR_i = \rho(X_i), \forall i \in N SCR_i = \rho(X_i), \forall i \in N \quad \text{and}$$
$$SCR_N = \rho(\textstyle\sum_{i=1}^{n} X_i) SCR_N = \rho(\textstyle\sum_{i=1}^{n} X_i) \quad (14)$$

2.4.1. *Pillar 2 and 3*

Pillar 2 of Solvency II is qualitative requirements. Qualitative requirements are made and determined by the government and risk management of insurance companies. There are 2 main objectives for this pillar: (1). Ensure that insurance companies run well and meet the standards of risk management; and (2). Ensuring that insurance companies have sufficient capital. If one of the objectives is not achieved, then the insurance company will be identified with a higher risk profile [6].

Pillar 3 of Solvency II requires insurance companies to disclose additional information needed by supervisors to carry out their duties as a supervisory body. This means that the analysis of the two previous pillars must be reliable. In general, there are 3 things underlie: (1). Measurement of financial condition and its sustainability; (2). Measurement of risk profiles and other assumptions data; and (3). Uncertain actions, including the accuracy of previous estimates and the sensitivity of the calculation of market volatility.

2.1. *Capital Allocation*

Capital allocation is commonly used when discussing when there are issues regarding different portfolios to combine the risks. This means that profits are derived by combining risks that need to be reallocated to individual portfolios.

2.5.1. Diversification

According to Balog [13] and Braun et al. [12], suppose that a set of portfolios $N = \{1,2,3,\ldots,n\}$, each with the amount of claim X_i. Furthermore $\rho(X_i)$ is defined as a risk measure for each portfolio i, $i = 1,2,\ldots,n$. Then diversification states that the sum of risks is at least equal to the risk of all wealth units:

$$\sum_{i=1}^{n}\rho(X_i) - \rho\left(\sum_{i=1}^{n}X_i\right) \geq 0 \quad (15)$$

$$\sum_{i=1}^{n}\rho(X_i) - \rho\left(\sum_{i=1}^{n}X_i\right) \geq 0$$

For example, in the same insurance company there are n portfolios, where the portfolio is exponentially distributed with the parameter λ. Next, Value-at-Risk (VaR) is used as a measure of risk, then for every $0 < \alpha < 1$, Value-at-Risk (VaR) becomes:

$$VaR_\alpha(X_i) = -\frac{\ln(1-\alpha)}{\lambda} \quad (16)$$

$$VaR_\alpha(X_i) = -\frac{\ln(1-\alpha)}{\lambda}$$

If a portfolio is combined, a new value is obtained, namely $\lambda . n^{-1}$. Therefore the Value-at-Risk (VaR) for the combined portfolio:

$$VaR_\alpha\left(\sum_{i=1}^{n}X_i\right) = -n\frac{\ln(1-\alpha)}{\lambda} \quad (17)$$

$$VaR_\alpha\left(\sum_{i=1}^{n}X_i\right) = -n\frac{\ln(1-\alpha)}{\lambda}$$

If we substitute equation (16) to (17), then obtained:

$$VaR_\alpha \sum_{i=1}^{n}(X_i) = n . VaR_\alpha(X_i) \quad (18)$$

$$VaR_\alpha \sum_{i=1}^{n}(X_i) = n . VaR_\alpha(X_i)$$

Merging Value-at-Risk (VaR) is the sum of individual Value-at-Risk (VaR) portfolios.

2.5.2. *Capital allocation strategy*

Assume that the amount of claim X_i on portfolio i, $i = 1,2,\ldots,n$, is a set of random variables Γ that real value in the opportunity space $(\Omega, \mathcal{F}, \mathbb{P})$. Therefore, a new concept will be introduced called the situation. The situation consists of: (1). A set of N from the portfolio used; (2). A variable $X_i, i \in N$ represents the number of possible claims for each portfolio; and (3). A measure of risk ρ. Therefore obtained :

$$\mathcal{A} = (N, (X_i), \rho), i \in N \quad (19)$$

$$\mathcal{A} = (N, (X_i), \rho), i \in N$$

Besides, define K as a collection of all conditions, with $\mathcal{A} \in K$, so that the definition of the capital allocation method is a function that determines the capital for each portfolio in a particular situation $\mathcal{A}$ which is expressed as [5], 16]-[17]:

$$\varphi^K : \mathcal{A} \to \mathbb{R}^N \quad (20)$$

A. Activity-based method

The capital allocation method was first introduced by Hamlen in 1977. The Activity-Based Method allocates mutual risk to portfolios compared to individual risk. For changing risk capital allocation situations, $\mathcal{A} \in K$ Activity-Based Method allocates it to the portfolio [15]-[16]:

$$\varphi_i{}^{AB}(\mathcal{A}) = \frac{\rho(X_i)}{\sum_{j=1}^{n}\rho(X_j)}\rho\left(\sum_{j=1}^{n}X_j\right) \quad (21)$$

$$\varphi_i{}^{AB}(\mathcal{A}) = \frac{\rho(X_i)}{\sum_{j=1}^{n}\rho(X_j)}\rho\left(\sum_{j=1}^{n}X_j\right)$$

B. Incremental method

According to Jorion [18], the Discrete Marginal Contribution capital allocation method is often called the Incremental Method. This method allocates capital proportionally to the large increase in risk of each portfolio. For capital allocation that changes with the $\mathcal{A}$ $\mathcal{A}$ ∈K, Discrete Marginal Contribution to the portfolio is:

$$\varphi_i^I(\mathcal{A}) = \frac{\rho(\sum_{j=1}^{n} x_j) - \rho(\sum_{j=1, j\neq k}^{n} x_j)}{\sum_{k=1}^{n}(\rho(\sum_{j=1}^{n} x_j) - \rho(\sum_{j=1, j\neq k}^{n} x_j))} \rho(\sum_{j=1}^{n} X_j)$$

$$\varphi_i^I(\mathcal{A}) = \frac{\rho(\sum_{j=1}^{n} x_j) - \rho(\sum_{j=1, j\neq k}^{n} x_j)}{\sum_{k=1}^{n}(\rho(\sum_{j=1}^{n} x_j) - \rho(\sum_{j=1, j\neq k}^{n} x_j))} \rho(\sum_{j=1}^{n} X_j) \quad (22)$$

3. Result and analysis

In this section, the problem discussion is carried out by following the appropriate research stages. Where it has been explained that in this study contains the allocation of capital in the insurance business based on solvency II, using the calculation of Solvency Capital Requirements (SCR) and capital allocation using Activity Methods and Incremental Method.

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3.1. *Analyzed Data*

In this study random simulation data used in the data obtained from the premium and claims calculation program. Where the process is as follows: Filled with a lot of data that will be used for research, which presents the number of months that is as much as 100. In the premium variable is filled with how much premium must be paid by the insured to the insurance company to bear the risk, which is 3,000,000 per year. After there is additional capital of 1,500,000, a data return is obtained, where the positive value represents the profit and the minus value represents the loss

3.2. *Return Normality Test*

Return normality test aims to determine whether the data return is normally distributed or not using the Kolmogorov-Smirnov test with the help of IBM SPSS Statistics 17 software, to determine whether or not there are outliers data. The results are given in Table 1.

Table 1. *Lilliefor Significance Correction*

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Return_1	.281	100	.000	.492	100	.000
Return_2	.300	100	.000	.459	100	.000
Return_3	.327	100	.000	.356	100	.000

a. Lilliefors Significance Correction

Using hypothesis H_0 : Data return is normally distributed, and H_1 : Data return is not normally distributed. The test criteria are accept H_0 if the significance value > 0.01; and reject H_1 if the significance value < 0.01. From Table 1. it is found that the significance value for *return_1*, *return_2*, *return_3* is 0.00000. On *return_1*, *return_2*, *return_3* significance value < 0.01, then H_0 is rejected. It means that *return_1* , *return_2*, *return_3*data are not normally distributed.

Therefore, it is necessary to do a Lilliefors test, which is carried out with the help of the IBM SPSS Statistics 17 software. Based on the Boxplot we can see outliers from each data return. It appears that: in *return_1* there are outliers data, namely: 18, 45, 68, dan 75; on *return_2* there are outliers data which are: 45, 56, 63, 86, 94; and in *return_3* there are outliers data which are: 7, 49, 62, 63, 64, 86.

There are several ways to normalize data that are not normal, that are: (1). Reducing the amount of data, meaning that the reduced data is outlier data that causes data not normally distributed; (2). Perform data transformation; and (3). Change the type of test. Because the data return is not normally distributed, a technique to reduce the amount of data is performed, and a lilliefors test is performed. So for data m = 85 there is no outlier data.

Next, the Kolmogorov-Smirnov test was used with the help of IBM SPSS Statistics 17, to test the normality of m = 85. Using the hypothesis that: H_0 : Data return without outliers are normally distributed, and H_1 : Data return without outliers are not normally distributed. The test criteria are accepted H_0 if the significance value > 0.01, and reject H_1 if the significance value < 0.01. The test results obtained that the significance value for data *return_1*= 0.014 > 0.01; for *return_2* data significance value = 0.059 > 0.01; and for *return_3* data significance value = 0.011 > 0.01. Therefore, H_0 is accepted. It means that the data return_1, return_2, and return_3 are normally distributed.

Based on the Kolmogorov-Smirnov test, the mean and standard deviation values are shown in Table 2.

Table 2. Mean values and standard deviations of the three returns

	Portfolio		
	Return 1	Return 2	Return 3
Number of return data	85	85	85
Mean (μ_i μ_i)	3,317,290.42	3,271,757.75	2,564,259.34
Standard Deviation ($\sigma_i \sigma_i$)	1,217,212.67	1,155,729.85	1,864,953.61

3.3. *Calculation of Solvency Capital Requirements (SCR)*

In this section, we determine the value of Solvency Capital Requirements (SCR) for the three portfolios using equation (10) with the value α = 0.01. Based on the data in Table 2, the SCR obtained for each portfolio is as follows:

- For portfolio 1:

Based on the standard normal distribution table, the value of $z = 2.3267 z = 2.3267$, so we get the value of $x > 6,149,379.13$ $x > 6,149,379.13$. This means that for portfolio 1 is estimated to have a risk value of IDR 6,149,379.13; or

$SCR_1 = VaR_{0.99}(X_1) =$ IDR 6,149,379.13

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$SCR_1 = VaR_{0.99}(X_1) =$ IDR 6,149,379.13 .Using the same method obtained:

- For portfolio 2:

Obtained value $x > 5,960,794.39$ $x > 5,960,794.39$. This means that for portfolio 2, it is estimated to have a risk value of IDR 5,960,794.39; or $SCR_2 = VaR_{0.99}(X_2) =$ IDR 5,960,794.39 $SCR_2 = VaR_{0.99}(X_2) =$ IDR 5,960,794.39.

- For portfolio 3:

Obtained value $x > 6,903,446.91$ $x > 6,903,446.91$. It means that for portfolio 3, it is estimated to have a risk value of IDR 6,903,446.91; or $SCR_3 = VaR_{0.99}(X_3) =$ IDR 6,903,446.91 $SCR_3 = VaR_{0.99}(X_3) =$ IDR 6,903,446.91.

3.4. *Diversification*

To find out the relationship and the relationship between each portfolio, a correlation of the three portfolios was carried out using equation (9), with the help of the IBM SPSS Statistics 17. The results are given in Table 3.

Table 3. Correlation Matrix

	X_1	X_2	X_3
X_1	1	0.059	-0.059
X_2	0.059	1	0.167
X_3	-0.059	0.167	1

Then if the three portfolios are combined, then by referring equation (7) a new mean is obtained, and by referring equation (8) a new standard deviation is obtained. The new mean value is $\sum_{i=1}^{3}\mu_i =$ $\sum_{i=1}^{3}\mu_i =$ 9,153,307.51 and variance = 2,629,334.76. Therefore, the distribution for the combined portfolio is $X_1 \sim N($ $X_1 \sim N($ 9,153,307.51, (2,629,334.76)^2).

Next, the calculation of the value of the combined portfolio risk is carried out in the same manner in section 3.3, and it is obtained that the value $x > 15,270,980.70$ $x > 15,270,980.70$. This means that for a combined portfolio, it is estimated to have a risk value of IDR 15,270,980.70.

Referring to equation (14), the total risk of all portfolios is $\sum_{i=1}^{n}\rho(X_i) =$ IDR 19,013,620.43 $\sum_{i=1}^{n}\rho(X_i) =$ IDR 19,013,620.43 ; while the risk of the total portfolio is $\rho(\sum_{i=1}^{n}X_i) =$

$\rho(\sum_{i=1}^{n} X_i) =$ IDR 15,270,980.70. here is an effect caused by diversification of IDR $19{,}013{,}620.43$ $19{,}013{,}620.43$ – IDR 15,270,980.70 = IDR 3,742,639.73 > 0 which means that if risks are averaged, each portfolio will benefit or profit..

3.5. Analysis of capital allocation strategies

As explained in the previous section, that the analysis of capital allocation strategies is carried out using the Activity-Based Method and Incremental Method approaches.

A. Calculation Activity-Based Method

The calculation of the value of Activity-Based Method for each portfolio uses equation (21). For portfolio 1:

$$\varphi_1^{AB}(\mathcal{A}) = \frac{6{,}149{,}379.13}{6{,}149{,}379.13 + 5{,}960{,}794.39 + 6{,}903{,}446.91} 15{,}270{,}980.70$$

$$= \frac{6{,}149{,}379.13}{19{,}013{,}620.43} 15{,}270{,}980.70$$
$$= \frac{6{,}149{,}379.13}{19{,}013{,}620.43} 15{,}270{,}980.70 \quad = 4{,}938{,}935.77$$
$$= 4{,}938{,}935.77$$

Using the same way calculations are performed for portfolio 2 and portfolio 3. Overall results are given in Table 4.

Table 4. Capital allocation with Activity Based Method

φ_1^{AB}	φ_2^{AB}	φ_3^{AB}
IDR 4,938,935.77	IDR 4,787,472.04	IDR 5,544,572.90

It means that the value of capital allocation for portfolio 1 is IDR 4,938,935.77; the value of capital allocation for portfolio 2 is IDR 4,787,472.04; and the value of capital allocation for portfolio 3 is IDR 5,544,572.90.

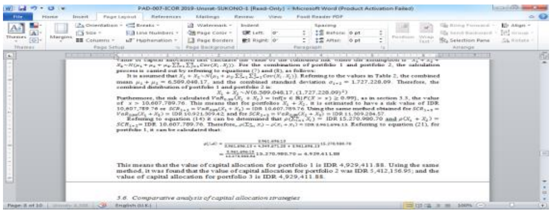
B. Calculation Incremental Method

The calculation of the Incremental Method value for each portfolio uses equation (22). Before calculating the value of capital allocation first calculate the value of the combined risk where the assumption is $X_1 + X_2 + X_3 \sim N(\mu_1 + \mu_2 + \mu_3, \sum_{i=1}^{3}\sum_{j=1}^{3} Cov(X_i, X_j))$ $X_1 + X_2 + X_3 \sim N(\mu_1 + \mu_2 + \mu_3, \sum_{i=1}^{3}\sum_{j=1}^{3} Cov(X_i, X_j))$. For the combination of portfolio 1 and portfolio 2, the calculation process is carried out by referring to equations (7) and (8), as follows:

It is assumed that $X_1 + X_2 \sim N(\mu_1 + \mu_2, \sum_{i=1}^{2}\sum_{j=1}^{2} Cov(X_i, X_j))$ $X_1 + X_2 \sim N(\mu_1 + \mu_2, \sum_{i=1}^{2}\sum_{j=1}^{2} Cov(X_i, X_j))$. Referring to the values in Table 2, the combined mean $\mu_1 + \mu_2 = 6{,}589{,}048.17$ $\mu_1 + \mu_2 = 6{,}589{,}048.17$, and the combined standard deviation $\sigma_{1+2} = 1{,}727{,}228.09$ $\sigma_{1+2} = 1{,}727{,}228.09$. Therefore, the combined distribution of portfolio 1 and portfolio 2 is:

$$X_1 + X_2 \sim N(6{,}589{,}048.17, (1{,}727{,}228.09)^2)$$

Furthermore, the risk calculate $VaR_{0.99}(X_1 + X_2) = \inf\{x \in \mathbb{R} | F(X > x) \geq 0.99\}$ $VaR_{0.99}(X_1 + X_2) = \inf\{x \in \mathbb{R} | F(X > x) \geq 0.99\}$, as in section 3.3, the value of $x > 10{,}607{,}789.76$ $x > 10{,}607{,}789.76$. This means that for portfolios $X_1 + X_2 X_1 + X_2$, it is estimated to have a risk value of IDR 10,607,789.76 or $SCR_{1+2} = VaR_{0.99}(X_1 + X_2) = \text{IDR } 10{,}607{,}789.76$ $SCR_{1+2} = VaR_{0.99}(X_1 + X_2) = \text{IDR } 10{,}607{,}789.76$. Using the same method obtained for $SCR_{1+3} = VaR_{0.99}(X_1 + X_3) = \text{IDR } 10{,}921{,}309.42$ $SCR_{1+3} = VaR_{0.99}(X_1 + X_3) = \text{IDR } 10{,}921{,}309.42$ $SCR_{1+3} = VaR_{0.99}(X_1 + X_3) = \text{IDR } 10{,}921{,}309.42$;and for $SCR_{2+3} = VaR_{0.99}(X_2 + X_3) = \text{IDR } 11{,}309{,}284.57$ $SCR_{2+3} = VaR_{0.99}(X_2 + X_3) = \text{IDR } 11{,}309{,}284.57$ $SCR_{2+3} = VaR_{0.99}(X_2 + X_3) = \text{IDR } 11{,}309{,}284.57$. Referring to equation (14) it can be determined that $\rho(\sum_{i=1}^{n} X_i) = \text{IDR } 15{,}270{,}980.70$ $\rho(\sum_{i=1}^{n} X_i) = \text{IDR } 15{,}270{,}980.70$ and $\rho(X_1 + X_2) = SCR_{1+2}\rho(X_1 + X_2) = SCR_{1+2}$= IDR $10{,}607{,}789.76$ $10{,}607{,}789.76$. Therefore, $\rho(\sum_{i=1}^{n} X_i) - \rho(X_1 + X_2) = \text{IDR } 3{,}961{,}696.13$ $\rho(\sum_{i=1}^{n} X_i) - \rho(X_1 + X_2) = \text{IDR } 3{,}961{,}696.13$. Referring to equation (21), for portfolio 1, it can be calculated that:



This means that the value of capital allocation for portfolio 1 is IDR 4,929,411.88. Using the same method, it was found that the value of capital allocation for portfolio 2 was IDR 5,412,156.95; and the value of capital allocation for portfolio 3 is IDR 4,929,411.88.

3.6. Comparative analysis of capital allocation strategies

Based on the calculation of the capital allocation strategy in section 3.4. and 3.5, we can summarize the value of capital allocation based on Activity Based Method and Incremental Method, as presented in Table 5.

Table 5. Comparison of Capital Allocation Values

Strategi	X_1	X_2	X_3
Activity Based Method	IDR 4,938,935.77	IDR 4,787,472.04	IDR 5,544,572.90
Incremental Method	IDR 4,929,411.88	IDR 5,412,156.95	IDR 4,929,411.88

Table 5 shows the value of capital allocation from the two methods above gets a value that is not significantly different. Therefore, it can be concluded that the two methods above can be used for the calculation of capital allocation strategies.

4. Conclusions

In this research, Value-at-Risk (VaR) is applied to Solvency II on Pillar 1, namely the calculation of Solvency Capital Requirements (SCR) and the calculation of Value-at-Risk (VaR). The positive value obtained in the Diversification process indicates that the insurance company can fulfill its obligations. Obtained a value that is not significantly different from the calculation of capital allocation with the Activity Based method and Incremental method so that both can be selected and applied in the calculation of capital allocation.

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