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Pure Premium Modeling for Property Fire Insurance Using Monte Carlo Method

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Abstract

Modeling pure premium of property fire insurance is an important aspect for insurance companies in managing risk. This article discusses the Monte Carlo method in modeling pure premium of property fire insurance. The Monte Carlo method is used to simulate various scenarios and loss factors due to property fire. Monte Carlo simulation offers an effective approach to modeling property fire risk. The results of this study are expected to provide an overview of the modeling of pure premium of property fire insurance and assist insurance companies in decision making and determining optimal premium prices.

Keywords: Pure Premium, Fire Insurance, Monte Carlo Method, Simulation, Property Risk.

1. Introduction

Insurance is one of the important instruments in risk management that functions to provide financial protection against various risks that can result in losses. Insurance is a protection mechanism for the insured against future risks, where the insured pays a premium to get compensation from the insurer (Rianto, 2023). In this context, property fire insurance is one of the forms of protection most needed by the community and companies. This is due to the large potential for losses due to fires that can occur suddenly and are difficult to predict. According to Ramli (2010), fire is a very large blaze that exceeds human capacity and strength. Fire is a serious threat that can cause major losses, not only to property, but also in terms of loss of life and injury, and can also affect the economic stability of a business or company. The danger of fire that occurs is usually caused by the poor quality of buildings and the environment, as well as the condition of the fire protection infrastructure that is not functioning optimally (Nurmayadi, 2018).

With the increasing value of property and assets owned, the need for protection against this risk is increasingly urgent. Premium is an amount of money that must be paid by the insured to the insurer in return for the risk protection provided. The amount is determined based on the level of risk borne by the insurance company (Kartini, 2015). Therefore, accurate premium pricing is very crucial to ensure that the insurance company can bear the risk without ignoring the competitiveness aspect in the market. In other words, insurance companies need to find a balance between covering potential losses and remaining attractive to potential customers. Premium pricing is one of the key elements in the management of non-life insurance businesses, such as property insurance. The main challenge in determining the premium is setting the right amount for coverage during the insurance period, usually one year. This process involves an in-depth analysis of historical claim data, as well as projections of possible future events. If the premium is set too low, the insurance company is at risk of significant financial losses. Conversely, if the premium is too high, the company could lose its competitiveness in the market, potentially losing customers. The component of the premium that only covers the risk of claims, without taking into account management costs or claim investigations, is known as a pure premium. Accurate determination of pure premiums is not only beneficial for insurance companies but also provides better protection for customers.

Given the unpredictable nature of fire risk, a more dynamic and adaptive approach is needed in premium modeling. One method that can be used is the Monte Carlo method. According to Arifin (2009), Monte Carlo is a probability simulation method that approaches the solution of a problem by taking samples from a random process. Monte Carlo simulation is a numerical method that uses random sampling to simulate various possible scenarios.

This allows organizations to generate probability distributions of risk outcomes and calculate the expected value and standard deviation of those outcomes. This method allows us to simulate various possible fire events, given that risks are not always normally distributed. By utilizing random simulations, we can model uncertainty and project the distribution of possible claims. Application of the method

Monte Carlo in fire insurance premium modeling provides significant advantages in terms of accuracy. With this method, insurance companies can identify various possible scenarios, including extreme scenarios that rarely occur but can cause large losses.

In the context of technology, advances in data analysis and computing accelerate the application of the Monte Carlo method in the insurance industry. In addition, the Monte Carlo method also allows for better decision-making in risk management. This not only benefits the company but also provides a sense of security for policyholders. In the context of insurance, this method is used to calculate premiums, risk values, and claim reserves more accurately, allowing companies to improve efficiency and risk management (Kroese, 2016).

Table 1: Research Gap

Author	Topics	Premium Modeling	Property Fire Insurance	Monte Carlo
Ariputri (2018)	Catastrophe reinsurance premium pricing	Yes	Yes	No
Dominiak & Zadlo (2022)	Measuring copula-based risk in non-life insurance portfolios	No	No	Yes
Rahim, Mostafiz, Friedland, Rhli, & Bushra (2023)	Flood risk analysis for homeowners	No	No	Yes
Ananda & Ayu (2023)	Fire Prevention & Protection Efforts as Part of Fire Safety	No	Yes	No
This research	Pure premium modeling for property fire insurance using the Monte Carlo method	Yes	Yes	Yes

2. Literature Review

2.1. Property Fire Insurance

Property fire insurance is a form of financial protection designed to protect property owners from losses due to fire. In this context, it is important to understand the risks associated with fire, including its causes, frequency, and economic impact. Setting the right premium based on risk analysis is crucial to maintain a balance between the protection provided and the competitiveness of the insurance company. Studies show that property owners often underestimate the risk of fire, even though fire statistics show that fire is one of the biggest causes of property losses in many countries (Smith & Jackson, 2018).

In some countries, fire insurance regulations are administered by the government to ensure that property owners receive appropriate protection. Some jurisdictions require fire insurance for commercial and residential properties. In the Indonesian context, the Financial Services Authority (OJK) regulates general insurance including fire insurance through OJK Regulation Number 69/POJK.05/2016 concerning the Implementation of Insurance Business. This regulation seeks to ensure transparency in insurance policies and claims (OJK, 2016).

2.2. Pure Premium

Pure premium is an estimate of the cost required to cover a claim based on the probability of the occurrence of the insured risk. According to Skipper and Kwon (2007), pure premium is calculated by multiplying the probability of a risk event (such as fire, death, or accident) by the expected value of the loss resulting from the event.

Fire insurance premiums are calculated by considering the risks faced. Some factors that influence the determination of premiums include:

(a) Property Value: The higher the property value, the greater the potential loss that the insurance company will have to cover.
(b) Location: Areas with higher fire risk levels will be subject to higher premiums.

2.3. Risk Analysis

Risk analysis focuses on identifying potential risks and evaluating their likelihood and impact on organizational goals. According to Kaplan and Garrick (1981), risk is defined as a combination of the possibility of an event and its consequences. Risk analysis is an activity that aims to determine the level of likelihood of the frequency of risk occurrence and its impact on achieving goals and objectives, taking into account the control measures that have been taken. The level of likelihood of risk occurrence and the magnitude of impact on achieving goals or objectives are then combined to produce an estimated risk level. Fire risk analysis plays an important role in determining insurance rates. By evaluating property attributes and available fire protection measures, insurance companies can set premiums that reflect the actual risk, thus providing a fair price for policyholders (Guanquan, 2005). Brown (2017) shows that properties equipped with advanced fire protection systems tend to get significant premium discounts, thereby reducing the burden of insurance costs for property owners.

2.4. Statistics and Distribution Theory

According to DR. Boediono (2014) statistics is knowledge related to methods, techniques or ways to collect data, process data, present data, analyze data and draw conclusions or inteIDRret data. Thus it is clear that statistics is a science about collecting, compiling, processing and analyzing data needed in making a decision.

The scope of statistics is divided into two, namely descriptive statistics and inferential/inductive statistics. Statistics that are concerned with methods or ways of describing, depicting or explaining data or are exploratory in nature are called descriptive statistics. In other words, descriptive statistics are more emphasized on data presentation so that the information contained in the data is easily understood by data users. Data can be presented numerically or graphically. Presenting data numerically will involve calculating descriptive measures such as average, standard deviation, variance, quartiles, percentiles and so on. While presenting data graphically can be through bar charts, pie charts, box plots, scatter plots or steam & leaf diagrams.

Statistics that are concerned with how to draw conclusions based on data obtained from samples to describe the characteristics or traits of a population or its nature is confirmatory is called inferential/inductive statistics. Population is the entire object, be it the result of counting or measuring which is limited by certain criteria. The quantity that characterizes the population is called a parameter, for example the average (μ) or standard deviation (α). While the sample is part of the population that we are concerned with (DR. Boediono, 2014). The quantity that characterizes the sample is called a statistic, for example the average ($\bar{x}$) or standard deviation (s).

A random variable is a rule that assigns a numerical value to an outcome of interest(Rudolf. J. Freund, 2003) or random variables are defined as numerical descriptions of experimental results, usually linking numerical values to each possible experimental outcome (J. Supranto, 2009).

Random variables are divided into two, namely discrete random variables and continuous random variables. A discrete random variable is one that can take on only α countable number of values (Rudolf, J. Freund, 2003) or a variable that only has the values 0,1,2,3,... where for each variable value there is a chance (Sudjana, 2005). Discrete random variables can only take on certain separate values, which are generally generated from the calculation of an object (J. Supranto, 2009).

Meanwhile, α continuous random variable is one that can take on any value in an interval (Rudolf, J. Freund, 2003) or is a non-discrete random variable, meaning that if it is a continuous variable then the value X is in the interval $-\infty < x < \infty$ or other limits (Sudjana, 2005). Continuous random variables are random variables whose values are generated from the results of measurements on an object (J. Supranto, 2009).

3. Objects and Methods

3.1. Objects

The main materials in this study are historical annual data on the frequency of house fires, the frequency of fire insurance policy holders, and house prices in West Jakarta.

3.2. Method

Model the number of claims and the magnitude of claims using a statistical model using the Monte Carlo simulation method to model the pure premium of property fire insurance. This approach simulates various future claim scenarios based on available historical data, so that we can obtain an accurate distribution of total claims in the future. The steps in this method are explained as follows:

3.2.1. Data collection

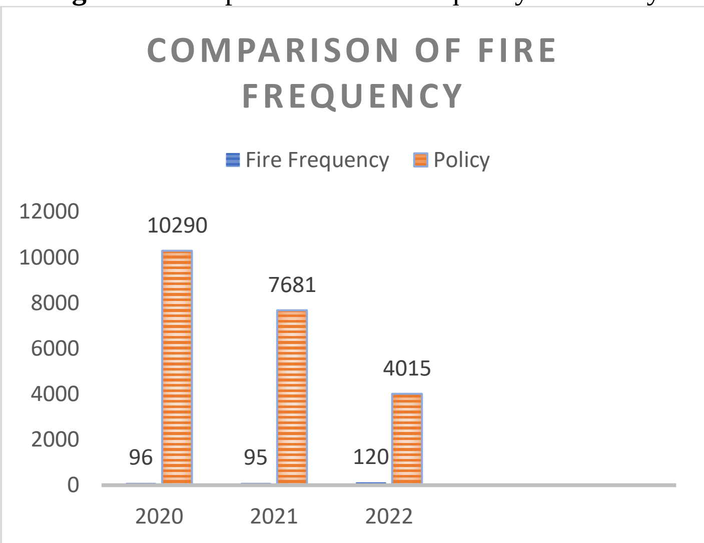
Collecting historical data in the form of the frequency of house fires in West Jakarta per year at the West Jakarta Central Statistics Agency (BPS), fire insurance policy data in the annual report of the Askrindo company, as well as property characteristics and property values in West Jakarta starting from IDR. 400,000,000 to IDR. 1,000,000,000 obtained from the website www.rumah123.com.

Table 2: Fire Frequency Data and Fire Insurance Policy for the period 2020-2022

Year	Fire Frequency	Policy
2020	96	10290
2021	95	7681
2022	120	4015
Amount	**311**	**21986**
Average	**103.6667**	**7328.6667**

In this data we assume that 311 house fires were fire insurance policy holders out of a total of 21,986 policies.

Figure 1: Comparison of Fire Frequency and Policy



In Figure 1 there is a decrease in policies on home fire insurance while the frequency of home fires increases every year.

Table 3: House prices (in million rupiah) in West Jakarta

House price (in million rupiah)	Group	Frequenc y
400 - 500	1	61
500 - 600	2	50
600 - 700	3	42
700 - 800	4	36
800 - 900	5	39
900 - 1000	6	48
1000 - 2000	7	35

Table 3 is a table of property value groupings in West Jakarta for the distribution of 311 house fires to each group randomly.

Figure 2: House Frequency with House Price (in million rupiah)

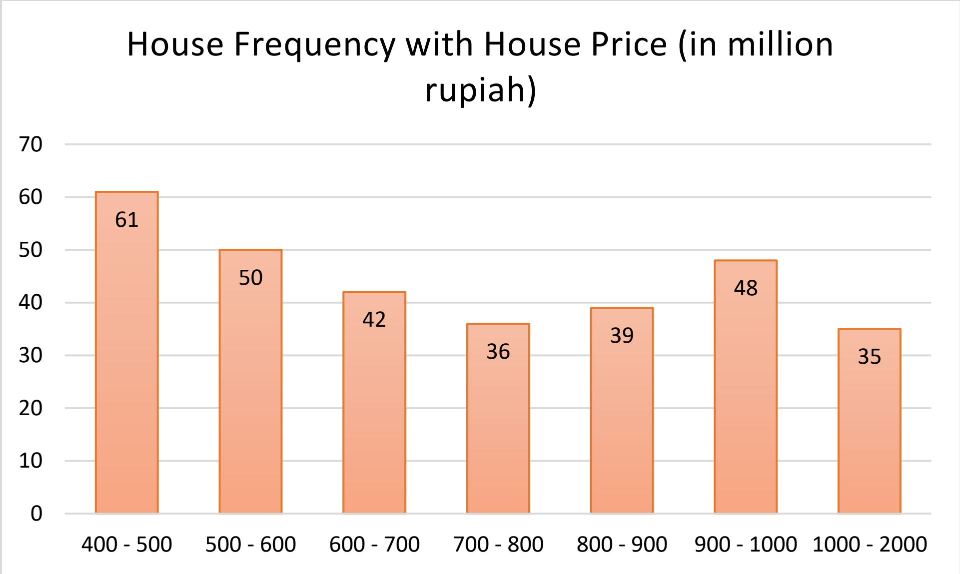


Figure 2 shows that the higher the property value, the less likely a fire is to occur.

3.2.2. Modeling Claims Distribution

Identifying claim distributions that fit the characteristics of the data. In this article we use the Normal and Binomial distributions.

3.2.2.1. Normal Distribution

The normal distribution is one of the distributions that is suitable for large claim data. Where this distribution has two parameters, namely and . The probability function of the normal distribution is as follows:$\mu\sigma$

$$f(x) = \frac{1}{x \cdot \sigma \cdot \sqrt{2\pi}} e^{\frac{-(x-\mu)^2}{2\sigma^2}} \tag{3.1}$$

Next, the equation for the expected value or average is:

$$E\left(X^k\right) = e^{k\cdot\mu+\frac{1}{2}k^2\sigma^2} \tag{3.2}$$

$$E(X) = e^{\mu+\frac{1}{2}\sigma^2} \tag{3.3}$$

Then to find the variance obtained from:

$$Var(X) = E(X^2) - \left(E(X)\right)^2$$
$$Var\ (X) = e^{2\mu+2\sigma^2} - (e^{\mu+\frac{1}{2}\sigma^2})^2 \tag{3.4}$$

3.2.2.2. Binomial Distribution

The binomial distribution can be used in insurance to estimate the frequency of fire claims on a number of properties over a given period. Each claim is assumed to be a Bernoulli trial, with two possible outcomes: the claim occurs or it does not. This model is particularly appropriate when each property has a fixed probability of fire and the risks between properties are independent. The binomial distribution formula is as follows:

$$P(N = x) = \binom{n}{x} p^x (1-p)^{n-x} \tag{3.3}$$

3.2.3. Monte Carlo Simulation

Monte Carlo simulation to estimate risk measures such as Value at Risk (VaR), Expected Shortfall (ES), and

Median Shortfall (MS). This simulation technique helps in predicting total future claims and assessing the risk of loss of the insurance company for individual policies. Monte Carlo simulation is conducted to predict the total value of future claims based on the distribution model that has been built. Following are the main steps in the simulation.

1) Collecting data on fire frequency and policyholders from a fire insurance company.
2) Generate the insurance company's loss values for a single policy for past, present, and future periods from the marginal distribution.
3) Calculate the net premium and the insurance company's risk of loss measure for a single policy based on the insurance company's realized losses generated under the assumed model.

3.2.4. Calculating Pure Premium

This premium is calculated based on the expected loss that may occur, without considering additional factors such as insurance company profits or administration costs. In other words, pure premium is the most basic approach in premium calculation, which only focuses on the risk of claims without any additions (loading) for other aspects. Pure premium can be calculated using the following formula

$$\Pi_x = E[X] \tag{3.4}$$

3.2.5. Risk Size

After the simulation is carried out, then calculate several risk measures to estimate the maximum loss that the insurance company might face:

3.2.5.1. Value at Risk (VaR):

Value at Risk(VaR) is a measure of risk used to estimate the maximum loss an insurance company may experience in a given period at a certain level of confidence (e.g. 99%). In the context of property fire insurance, VaR helps companies determine the potential loss that could occur due to an insurance claim in a worst-case scenario. The general formula for calculating VaR is:

$$VaR_\alpha = \mu + Z_\alpha . \sigma \tag{3.5}$$

3.2.5.2. Expected Shortfall (ES):

Expected Shortfall(ES), also known as Conditional VaR, calculates the average loss that occurs outside the VaR value. This provides a more complete picture of the potential losses that an insurance company faces, especially in extreme situations, such as a major fire that causes many claims. The formula for calculating Expected Shortfall is:

$$ES_\alpha = \frac{1}{1-\alpha}\int_{-\infty}^{-VaR_\alpha} x \,.\, f(x)\, dx \tag{3.7}$$

3.2.5.3. Median Shortfall (MS):

Median Shortfall(MS) is a risk measure that calculates the median of losses in a worst-case scenario, focusing on the middle value rather than a particular percentile. In the context of property fire insurance, MS provides a more robust perspective, especially when the loss distribution is asymmetric or contains outliers. The formula for calculating Median Shortfall is:

$$MS = median(X)\ untuk\ X < -VaR_\alpha \tag{3.8}$$

4. Results and Discussion

Table 4: Simulation of Loss and Claim Value

Simulation of Loss and Claim Value			
House Fire Identification	Home group	Loss Value	Claim Value

1	6	IDR. 55,000,000	IDR2,750,000
2	4	IDR. 59,000,000	IDR2,950,000
3	1	IDR. 32,000,000	IDR1,600,000
4	5	IDR48,000,000	IDR2,400,000
.	.	.	.
.	.	.	.
.	.	.	.
308	5	IDR. 30,000,000	IDR1,500,000
309	2	IDR. 45,000,000	IDR2,250,000
310	6	IDR. 38,000,000	IDR1,900,000
311	2	IDR20,000,000	IDR1,000,000
		Amount	**IDR661,900,000**
		Average	**IDR2,128,296**
		Standard Deviation	**IDR836,720**

In Table 4 frequency of housing value groups, House Group data, loss values, and claim values (5% of loss values) are simulated using random values. After that, find the average claim value and standard deviation to start the Monte Carlo simulation.

Table 5: Descriptive Statistics for Monte Carlo Simulations

Simulation	1000
Claim Frequency	1.41%
Average Claim Value	IDR2,128,296
Standard Deviation of Claim Value	IDR836,720

Calculating Monte Carlo simulation with 1000 iterations, Claim Frequency of 1.4% of fire claims per policyholder, mean, and standard deviation of claim values from 311 home fires.

Table 6: Monte Carlo Simulation

Monte Carlo Simulation			
Simulation	Claim Frequency	Claim Value	Total Claims
1	3	IDR2,957,888	IDR8,873,663
2	3	IDR2,020,819	IDR6,062,457
3	3	IDR2,845,816	IDR8,537,448
.	.	.	.
.	.	.	.
.	.	.	.
999	4	IDR3,359,569	IDR13,438,278

1000	3	IDR2,661,879	IDR7,985,638
		Pure Premium	**IDR11,021,688**
		VaR	**IDR30,474,455**
		(ICE)	**IDR34,863,613**

In Table 6 a random calculation of 1000 iterations is performed with the claim frequency being a simulation of a binomial distributed random sample (and) and the claim value being a simulation of a normally distributed random sample (and). From the calculation of the Monte Carlo simulation using Google Spreadsheets in table 4.4. a pure premium can be obtained which is the expectation or average loss (total claim) that may occur of IDR11,021,688, Value at Risk (VaR) with 99% confidence represents the maximum loss that may be experienced by the insurance company of IDR30,474,455, and Expected Shortfall (ES) where the expected loss that occurs in the worst case scenario is IDR34,863,613.$n = 36 p = 0.14 \mu = 2128296\, \sigma^2 = 836720$

Table 7: Claim Filter

Simulation	Total Claims Filter
1	0
2	0
3	0
.	.
.	.
.	.
999	0
1000	0
(MS)	**IDR33,869,875**

In Table 7 we perform data cleaning from total claims that exceed the VaR value to find the Median Shortfall (MS) value. The Median Shortfall (MS) value is obtained, which means the middle value of the total claims that exceed the VaR value limit of IDR33,869,875.

4.1. Results

In table 4.4. random calculation is done as many as 100 iterations with claim frequency is a simulation of binomial distributed random sample (n=36 and p=0.14) and claim value is a simulation of normal distributed random sample (and). From the calculation of monte carlo simulation using Microsoft Excel in table 4.4. pure premium can be obtained which is the expectation or average loss (total claim) that may occur of IDR11,021,688, Value at Risk (VaR) with 99% confidence represents the maximum loss that may be experienced by the insurance company of IDR30,474,455, and Expected Shortfall (ES) where the expected loss that occurs in the worst case scenario is IDR34,863,613.$\mu = 2128296\, \sigma^2 = 836720$

4.2. Discussion

The net premium of a fire insurance company needs to collect at least IDR11,021,688 in premiums from each policy to cover possible claims (without administration fees, profits, etc.).

The VaR in the calculation is IDR30,474,455, which means that in 99% (the confidence level used) in the simulation, the claim will not exceed IDR30,474,455. In other words, there is a 1% chance that the claim will exceed this amount in the worst case scenario.

Expected Shortfall (ES) is the average loss that occurs in the worst case (in 1% of the highest loss events). The value of IDR34,863,613 means that if the claim exceeds VaR (IDR30,474,455), the average loss in the simulation reaches IDR34,863,613.

The Median Shortfall (MS) of IDR9,905,783 shows that among all claims exceeding the VaR of IDR30,474,455, the median of these claims isIDR33,869,875. This means that half of the claims that are greater than the VaR are less than or equal toIDR33,869,875, and the other half is greater than that amount.

5. Conclusion

The pure premium of IDR11,021,688 is the average amount required to cover a claim. This is the basis for the premium price that will be charged on a fire insurance policy. VaR of IDR 30,474,455 shows that the company can estimate a maximum claim of this amount in 99% of simulations. It is very important to have sufficient cash reserves to handle adverse risk scenarios. Expected Shortfall (ES) of IDR 34,863,613 as additional information that in extreme situations where claims exceed IDR 30,474,455, the average additional loss will reach IDR 34,863,613. This provides a more complete picture of the high risk of loss that may be faced by insurance companies. The Median Shortfall (MS) of IDR 9,905,783 shows the median value of claims that occur under the extreme scenario, providing additional perspective on the distribution of extreme claims. The MS shows that most claims that exceed VaR tend to be below the value of IDR 9,905,783, and the other half are above.

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