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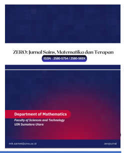

Ruin Probability Model for Disaster Insurance Companies: A Systematic Literature Review

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ABSTRACT

Ruin probability modelling is a crucial aspect for insurance companies that is very important and urgent to maintain the company's solvency. Ruin probability modelling helps identify insolvency risks, so companies can take timely preventive measures before it is too late. This research will present a systematic literature review (SLR) using a bibliometric analysis approach with the support of VOSviewer software, utilising the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method. The data sources used in this study came from 3 databases, namely Scopus, ScienceDirect and Dimensions, which resulted in 9 articles relevant to the topic under study. The results identified research gaps that could be an opportunity for future exploration. This research is expected to provide academic and practical contributions in developing ruin risk mitigation strategies in disaster insurance companies facing natural disaster uncertainty.

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1. INTRODUCTION

Indonesia is one of the most vulnerable and disaster-risk countries in the world. In addition to being the largest archipelago, Indonesia's islands lie on three tectonic plates, the Australian, Pacific and Eurasian plates, with more than 128 active volcanoes and around 150 rivers crossing the region [1]. Indonesia is also an archipelago along the Pacific Ring of Fire [2]. This condition makes Indonesia vulnerable to earthquakes, tsunamis, volcanic eruptions, and landslides [1]. In addition, forest and land fires in Indonesia are natural disasters that often occur yearly, especially during the dry season [3]. Therefore, it is necessary to be aware of the various types of disasters that often occur in Indonesia, be it tsunamis, earthquake risks or others [4].

Disasters are a real threat to the people of Indonesia. Indonesia has experienced many catastrophic events, such as the 2004 Aceh Tsunami, the 2006 Yogyakarta earthquake, the 2010 eruption of Mount Merapi in Central Java, the 2010 Mentawai Tsunami, and various other disasters. These disasters are evidence of Indonesia's high vulnerability to such events [1]. Even a recent disaster in Indonesia was the 2022 earthquake in Cianjur, one of the most severe earthquake impacts and had the highest number of casualties in Cianjur Regency [5]. Natural disasters can cause physical damage, injury, disability, human death, and economic problems, therefore, all elements of society have an important role before, during, and after the event, the dominant disasters that occur in Indonesia are floods, landslides, strong winds, volcanic eruptions, earthquakes, tsunamis, forest and land fires, and drought [6]. Therefore, insurance is needed to avoid risks that can be detrimental in the future.

Insurance is a contractual agreement between two parties, namely the insured party (customer) and the insurer (insurance company), in which the insured party pays a premium to the insurer. In return, the insurer will provide financial compensation (claim) to the insured party in the event of an insured event [7]. Insurance companies have concentrated market power to determine product pricing and design, set contract terms, and decide to whom and when to pay claims [8]. The insurance industry has an important role in achieving sustainable development by protecting individuals and families from falling into poverty in the event of a loss caused by an insured hazard [9]. There are also agreements between insurance companies and customers, where customers pay an agreed-upon premium for losses due to natural disasters. Among these agreements, insurance companies are responsible for providing coverage against the risk of loss due to natural disasters or risks included in insurance[10]. Disaster insurance mechanisms can reduce and mitigate disaster losses and play an important role in protecting future lives, livelihoods and infrastructure [11]. As economic losses from natural disasters are expected to increase, it is important to study risk reduction strategies, including individual asset owners' investment in damage reduction (mitigation) measures [12].

Some studies have discussed model development in insurance companies from various countries. Research is carried out on the problems of the affiliated area. Such as Ohori developing a mathematical model to calculate the probability of destruction due to storms and floods, and providing risk financing strategies for the railway business [13]. Kalfin et al. developing a Compound Poisson with Jumps-based insurance premium model and cross-subsidization, which takes into account disaster risk and economic growth to create fairer premiums throughout Indonesia [14]. Pothon et al. analyzing the factors of low earthquake insurance participation in California, focusing on the influence of premium price and risk perception [15], and Ma & Jiang created a Pareto-based risk optimization model within the GMPP (Government, Market, and Public Partnership) framework to ensure a balance between insurance supply and demand and improve market stability [16].

Although several studies examine the development of various models in insurance companies, there is no research that discusses the modelling of ruin probability that is more specific to disaster insurance companies. This research is fundamental because disaster insurance companies, especially in Indonesia, are very vulnerable and have a probability of ruin because Indonesia is a country prone to natural disasters. Therefore, there is a need for research that specifically discusses the probability of ruin in disaster insurance companies. In addition, the following have not been researched in previous literature reviews: selection of articles reviewed by the systematic literature review (SLR) procedure, bibliometric analysis, determination of research objectives related to ruin probability models in disaster insurance companies, and opportunities and challenges for future research.

This research will focus on the design of modelling the probability of ruin in disaster insurance companies with a review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method, which uses a detailed flowchart to improve the fit between the articles obtained and the topic under study. This process has three main stages: collecting, selecting and reviewing articles. All stages are conducted independently, without conflict of interest, to minimize bias. The article collection stage was conducted based on criteria checked through the Scopus, ScienceDirect, and Dimensions database search engines. Then, articles obtained at this stage were screened at the next stage by reading the abstracts and full texts of all articles. Finally, the review stage was conducted based on discussing the probability of ruin of disaster insurance companies in the articles. After the review, we also analyzed and discussed future research opportunities. This research will focus on the novelty of the probability of ruin for disaster insurance companies, which needs to be addressed in the future.

2. RESEARCH METHOD

2.1 Disaster Insurance

Natural disaster insurance aims to protect assets and individuals from financial losses caused by natural disasters such as earthquakes, floods, fires, tsunamis, landslides, and volcanic eruptions. Risk is transferred from the community to the insurance company in natural disaster insurance. Disaster insurance is an agreement between the insurance company and the customer, where the customer pays an agreed premium for losses due to natural disasters, among these agreements, the insurance company is responsible for providing coverage against the risk of loss due to natural disasters or risks included in the insurance [10].

There are already many disaster insurance companies in Indonesia, one of which is the Jasindo insurance company, which can be used for earthquake, fire, volcanic eruption, and tsunami insurance. Disaster insurance mechanisms can reduce and mitigate disaster losses and play an important role in protecting future lives, livelihoods and infrastructure [11]. As economic losses from natural disasters are expected to increase, it is important to study risk reduction strategies, including individual asset owners' investment in damage reduction (mitigation) measures [12].

2.2 Risk Theory

Risk theory focuses on modelling the number of claims, which consists of individual and collective risk models. Individual risk models attempt to model the number of claims at the individual claim level, and these random variables are usually summed to obtain an estimate of the total portfolio risk. However, portfolio-level risk models are often more reasonable to use. Moreover, reality generally remains 'computationally efficient and close to reality' even if some policy information is ignored in the model [17].

The financial reserve of the insurance company at time t is $X(t)$, which can be represented by a surplus equation (1).

$$\boldsymbol{X(t) = X(0) + P(t) - S(t)}, \tag{1}$$

The initial capital of the company is $t > 0$ and $N(0)$. Function $P(t)$ is the revenue process of the firm at time t. Function $S(t)$ is the claims process, which indicates the total amount that the firm has to pay to consumers at time t.

Suppose the stochastic process $\{N(t); t \geq 0\}$ denotes the number of claims arising from the risk portfolio in the time interval $(0, t]$. If the sequential claim sizes are $Z_1, Z_2 \dots \dots Z_n$, then the total number of claims in the time interval $(0, t]$, is shown by equation (2).

$$\boldsymbol{S(t) = \sum_{i=1}^{N(t)} Z_i}, \tag{2}$$

which makes sense if $N(t) = 0$, and $S(t) = 0$.

The classical risk process model, $\{N(t)\}$ is considered as a homogeneous Poisson process i.e. a Poisson process with stationary and independent increments, with parameter λ and claim size $Z_1, Z_2 \dots \dots Z_n$, considered as independent and identically distributed (iid) random variables with cumulative distribution function $F(\cdot)$. Furthermore, the processes $\{N(t)\}$ and Z_i are considered mutually independent. From these assumptions, we can know that $\{S(t); t \geq 0\}$ is a compound Poisson process. The classical risk model can be expressed as equation (3).

$$\boldsymbol{X(t) = X(0) + ct - \sum_{i=1}^{N(t)} Z_i}, \tag{3}$$

where $t > Z_1, Z_2 \dots \dots Z_n$ and is independent of $\{N(t)\}$ Poisson process.

2.3 Renewal Risk Model

The renewal risk model, also referred to as the Sparre Andersen model, has the following conditions:

1. Claim size process: The claim size $(X_k)_{k\in\mathbb{N}}$ is a positive i.i.d. distributed random variable with mean up to $\mu = E[X_1]$ and variance up to $\sigma^2 = Var[X_1] \leq \infty$.
2. Claim time: Claims occur at the realization of random times $0 < B_1 < B_1 < \cdots B_n$.
3. Claim arrival process: The claim arrival process is an update process, with the number of claims at time interval $[0, t]$ denoted as equation (4).

$$N(t) = sup\,\{n \geq 1: B_n \leq t\}\,, t \geq 0, \tag{4}$$

with the convention $sup\,\emptyset = 0$.

4. Time between claim arrivals: The inter-claim times $A_1 = B_1, A_k = B_k - B_{k-1}, k = 2, 3, \dots N$, are i.i.d. distributed with finite mean $E[A_1]$.
5. The rows (X_k) and (A_k) are independent: The process of total claim size $(S(t))_{t\geq 0}$ is defined as equation (5).

$$\boldsymbol{S(t) = \begin{cases} \sum_{i=1}^{N(t)} Z_i, & N(t) \geq 0 \\ 0, & N(t) = 0 \end{cases}} \tag{5}$$

from the conditions described above, a risk process, also referred to as a risk reserve process or surplus process, $(U(t))_{t\geq 0}$ can be formed, which is defined by the equation (6).

$$\boldsymbol{U(t) = u + ct - S(t), \qquad t \geq 0} \tag{6}$$

where $u \geq 0$ denotes the initial capital or surplus, and $c > 0$ denotes the premium income rate.

2.4 Probability of Ruin

Disaster insurance companies have a probability of ruin where ruin will occur when the surplus value is negative, $U(t) < 0$ for $t \geq 0$, if this happens for the first time then this situation is called ruin in disaster insurance companies. Ruin of the insurance company is defined by equation (7).

$$\boldsymbol{T = \min\{t: t \geq 0\ \&\ U(t) < 0\}} \tag{7}$$

Equation (7) is the definition of the time of ruin. However, if T is defined as $T = \infty$ with $U(t) \geq 0$ for all $t \geq 0$, then the insurance company will not experience ruin or ruin does not occur. At the same time, the probability of bankruptcy of the insurance company is defined by equation (8).

$$\boldsymbol{\Pr(T < \infty)}, \tag{8}$$

the probability of ruin will occur when the ruin T is infinite.

2.5 Method

The method used in this study is a bibliometric analysis approach with the support of VOSviewer software. Bibliometric analysis is a branch of science that analyses and evaluates scientific publications and related information [18]. It involves using statistical and informatics methodologies to assess the production, citation, and dissemination of Knowledge in the scientific literature [19]. Bibliometric studies can measure the performance and contributions of individuals, institutions, and disciplines and understand the interactions and relationships between disciplines and publications. It can help identify and evaluate trends and issues in the scientific literature [20]. Researchers, government, and industry can use the results of bibliometric analyses to understand developments and contributions in scientific fields and to determine future research directions [21].

VOSviewer is bibliometric software used to visualize and analyze scientific publication data [22]. VOSviewer allows users to visualize citation, co-citation, and co-word analysis data in the form of graphs and diagrams that are intuitive and easy to accept [23]. VOSviewer can assist researchers and analysts in analyzing citation networks, finding relationships between fields, and understanding trends and issues in the scientific literature [24]. This software also helps determine the direction of future research and gain insight into the performance and contributions of individuals, institutions, and fields of science. VOSviewer has an easy-to-use user interface and can be used with data derived from various sources, such as Scopus, Web of Science, and Google Scholar. The research allows users to visualize and analyze public data [25]. VOSviewer was chosen for its interactive visualisation, ease of use, specific capabilities for bibliometrics, and free availability. Compared to other software that is more complex or requires programming skills, VOSviewer is an effective and efficient solution for bibliometric analysis and mapping.

This study utilises the Preferred Reporting Items for Systematic Reviews and Meta Analysis (PRISMA) method introduced by [26]. PRISMA provides guidelines for conducting systematic literature reviews, as Stovold et al. described [27]. According to Moher et al. [26], applying PRISMA in research can improve the quality of the literature review regarding the methodology and results obtained. PRISMA has four stages, namely, identification, screening, eligibility, and inclusion, and it includes the following so that it can be used as material for a literature review. This literature search is focused on obtaining in-depth information on ruin probability models for disaster insurance companies. Therefore, the source articles should address the combination of keywords based on Table 1.

Table 1. Relevant keywords.

Keyword	Search term
A	(“Ruin” OR “Probability Ruin” OR “Bankruptcy” OR “Bankruptcy Probability” OR “Risk” OR “Losses”)
B	(“Disaster Insurance”)

In the first stage of PRISMA, namely identification, a systematic literature search was conducted in the Scopus and Dimensions databases with a time limit of ten years. The literature collection for this study was carried out based on the following criteria:

a. The articles are published in the Scopus, ScienceDirect, and Dimensions databases.
b. Journals published from 1 January 2014 to 31 December 2024.
c. Articles are available in full text.
d. Articles are written in English, and
e. Articles must use the word combinations in Table 1.

Then, the next stage is the screening process, which is carried out based on duplicating articles, abstracts, and titles. This stage aims to ensure that the selected articles are accurate, relevant, and fulfil the predetermined selection criteria, thus allowing for further analysis. The process at the screening stage follows the procedure proposed by Firdaniza et al. [28], namely:

- Duplicate articles were removed from all three databases to ensure accuracy and diversity.
- Article selection focused on the title and abstract, representing the most descriptive part of the overall content. In addition, this stage also saves time in the selection process. Articles with titles and abstracts that did not match the research criteria and topics were excluded from this stage.

Next came the eligibility stage, where articles were selected by thoroughly reading all sections. After abstract and title screening, articles were selected by reading the entire content. This stage ensures the selected articles are relevant to the specified criteria and research topics [29]. Articles selected at this stage enter the inclusion stage by fulfilling the criteria and are relevant to the research topic, which will be analyzed based on the research question (RQ) as follows:

a. RQ1: What variables are used in modelling the ruin of insurance companies?
b. RQ2: What distributional approach is used to model the ruin of insurance companies?
c. RQ3: What are the primary methods used to model the ruin of insurance companies?
d. RQ4: What techniques, open challenges, and recommendations exist for future research on the probability of ruin in disaster insurance?

3. RESULT AND ANALYSIS

3.1 Results of the article acquisition on Scopus, ScienceDirect, and Dimensions databases

The selection of Scopus, ScienceDirect, and Dimensions databases in this systematic literature review study was based on considerations of credibility, coverage, and ease of access to relevant articles. Scopus was chosen because it is one of the largest and most reliable databases, providing articles from various disciplines and equipped with citation analysis that facilitates the search for influential literature. ScienceDirect was used because it provides direct access to full-text articles from leading journals, particularly in the fields of science and technology relevant to the focus of this research. Additionally, Dimensions was selected because it offers broader coverage, including open-access publications, research data, and interactive connections between articles, supporting comprehensive literature exploration. The selection of these three databases is considered more appropriate compared to alternative databases such as Google Scholar, which may contain unverified literature, or ProQuest and EBSCO, which tend to focus more on social sciences and business, as well as Web of Science, which has access restrictions on some full-text articles.

The data search results on the Scopus, Science Direct, and Dimensions databases were carried out with several keywords applied to the "title, abstract, and keywords". The first step was to search for all papers related to the keywords ("Ruin" OR "Probability Ruin" OR "Bankruptcy" OR "Bankruptcy Probability" OR "Risk" OR "Losses"). From the search activity, 56,541 articles were obtained from the Scopus database, 1,545 articles from the Science Direct database, and 19,002 articles from the Dimension database, then the researchers applied an inclusion filter using two new keywords, namely ("Disaster Insurance"), which aims to obtain papers that include natural disaster data when examining bankruptcy. In this second round, 881 articles were obtained from the Scopus database, 29 from the Science Direct database, and 151 from the Dimensions database. The final process of filtering by combining the keywords ("Ruin" OR "Probability Ruin" OR "Bankruptcy" OR "Bankruptcy Probability" OR "Risk" OR "Losses") AND ("Disaster Insurance"), obtained 31 articles from the Scopus database, 14 articles from the Science Direct database, and 12 articles from the Dimensions database. The following is a summary of the results of the filtering process on both keywords presented in Table 2.

Table 2. Search results for relevant keywords.

Keywords	Scopus	ScienceDirect	Dimensions
A	56.541	1.545	19.002
B	881	29	151
A AND B	31	14	12

3.2 Final Results of Article Acquisition based on PRISMA method

The article screening procedure was carried out systematically by following the PRISMA flow, which began with the identification, screening, eligibility, and including stages. This procedure aimed to ensure that the selected articles were of high quality, relevant, and appropriate in answering the research questions that had been formulated. Based on the relevant keyword search results in Table 2, 57 articles were reviewed and analyzed using the PRISMA method. The researchers identified 25 duplicate articles and consequently excluded them from consideration, resulting in 32 articles. Then, the researchers conducted a title and abstract check analysis to ensure the alignment of each article with a focus on the probability of ruin in disaster insurance companies, resulting in 12 articles being analyzed. The researchers comprehensively reviewed the 12 articles regarding variables, distribution, and research methodology. The researchers excluded the type of insurance company and the data used. After rigorous assessment, nine articles were deemed suitable for further research and proceeded to the review stage with the keywords ("Ruin" OR "Probability Ruin" OR "Bankruptcy" OR "Bankruptcy Probability" OR "Risk" OR "Losses") AND ("Disaster Insurance"). Figure 1 presents the steps to select accepted or rejected articles.

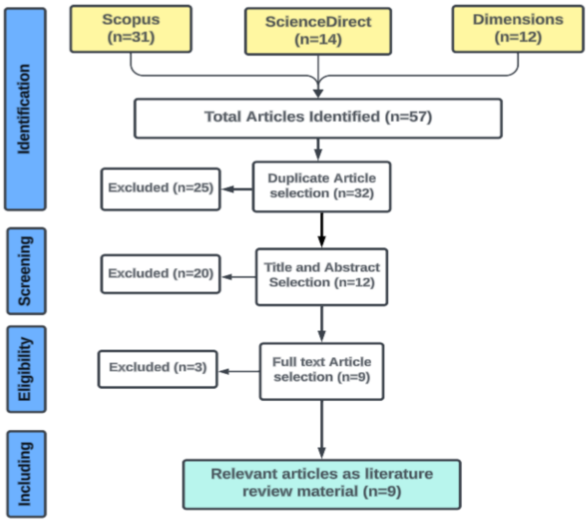

Figure 1. PRISMA diagram.

3.3 Bibliometric Analysis.

Bibliometric analysis is often used for literature analysis to obtain a bibliographic overview of a scholarly selection of widely cited publications. This analysis can recover author production lists, national or subject bibliographies, or other specialised subject patterns [30]. The researchers conducted a bibliometric analysis using VOSviewer software. VOSviewer is a computer program used for bibliometric mapping. This software has good visualisation and provides clear relationships among different nodes in the network image [31]. Figure 2 shows the visualisation of the co-occurrence-word relation with the help of VOSviewer software, with the size of the circle of each word reflecting the frequency of discussion of frequently discussed words in the nine selected articles. The larger the circle, the more frequently the word is discussed. Conversely, if the size is small, the word is rarely discussed. Then the connecting lines between the circles describe the relationship of words in the article, and the connecting lines between words show how close the relationship between the words is. The colour of the circles in Figure 3 indicates the clusters in the articles discussed; the same colour indicates similar clusters. Then, the distance between the circles illustrates how related the words are; the closer the distance, the stronger the relationship. The following Figure 2 shows the Visualisation of Co-Occurrence-Word Relation.

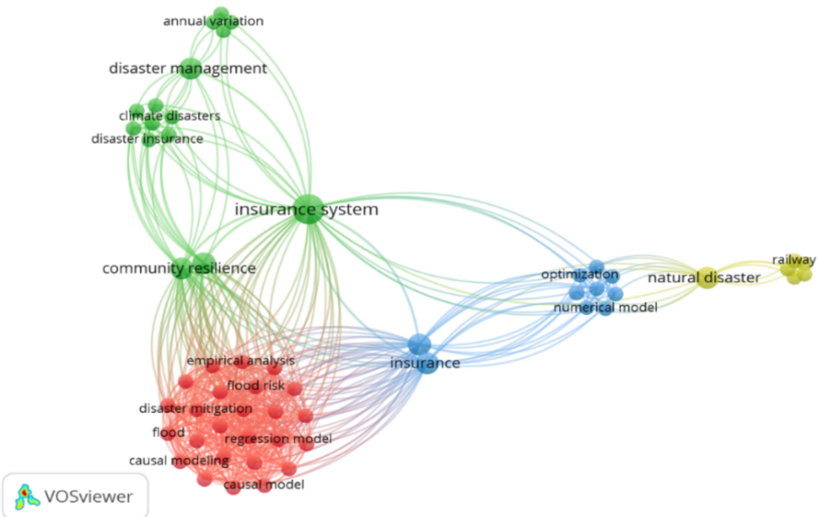

Figure 2. Visualization of Co-Occurrence–Word Relation.

Figure 2 shows five groups with different colours: blue, yellow, green, and red. The figure illustrates the size of the circles containing words of different sizes, where the word “Insurance System” has a larger dominant size, followed by “Insurance”, “Natural Disaster”, and “Disaster Management”, which indicates that the word is often used in the nine articles. The word ‘Disaster insurance’ is relatively small, indicating that it is rarely discussed in the nine articles. Figure 3 shows the mapping of keywords that appear in scientific articles based on the year of publication, so that it can provide an overview of the dynamics of science and the direction of research development. The following Figure 3 shows the Visualization of co-occurrence-year.

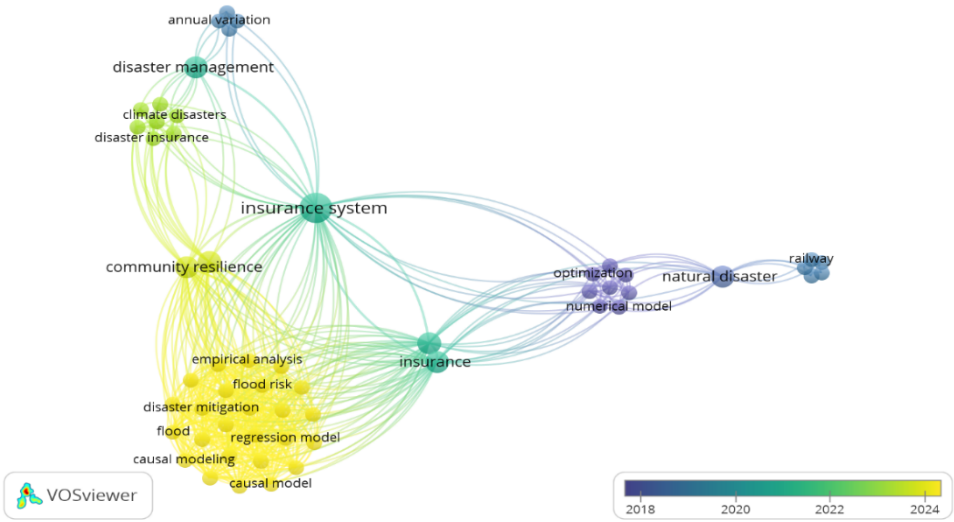

Figure 3. Visualization of Co-Occurrence–Year.

Figure 3 shows the mapping of keyword circles by year, where the years used are 2015 to 2024. The colour change in the keyword circle in Figure 3 shows that the more yellow the word is, the more it is often used in recent research; otherwise, if the colour is darker towards purple, then the word is used in research in the old year, namely 2015. Based on the topic mapping image of the nine articles, no keywords are used in this study, and there are no words "Probability Ruin", "Probability Bankruptcy", and "Disaster Insurance". This shows that no research has discussed these keywords, so it is an opportunity for future research to explore further the probability of the ruin model in disaster insurance companies.

Then, co-occurrence-density analysis is used to map the level of relationship density between keywords in the reviewed literature. According to Riaman et al. the brightest indicates that a topic is widely used in research, while the less bright indicates that a topic is rarely used [32]. This analysis is done by building a density map based on the keywords most frequently in scientific articles. Words with high frequency and strong connectivity will appear denser, while less common words have lower density. Figure 4 shows a Visualization of the co-occurrence density.

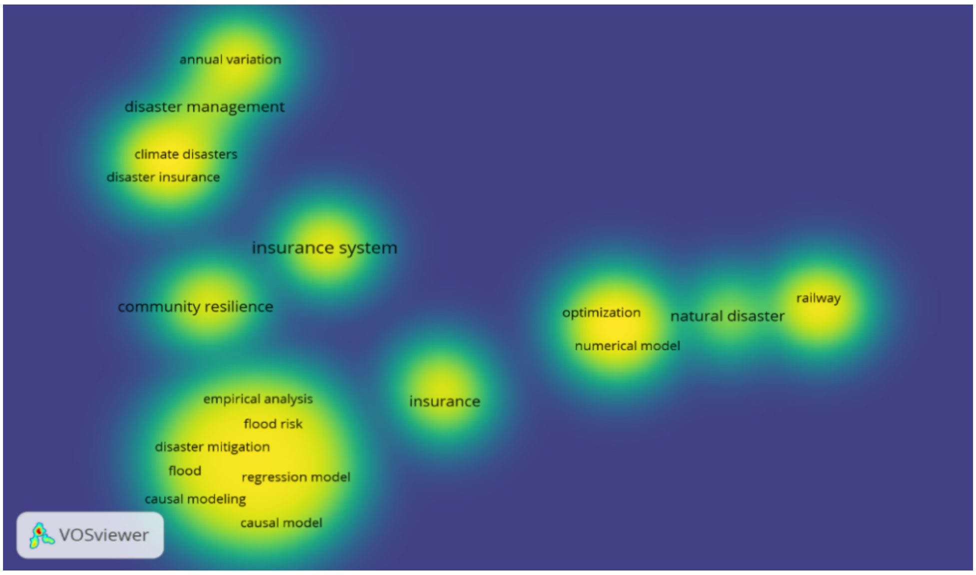

Figure 4. Visualization of Co-Occurrence– Density.

Figure 4 shows the density of research topics related to the probability of ruin in disaster insurance companies using VOSviewer, which illustrates the interrelationships between topics in a research field. Yellow indicates keywords with high frequency and frequent occurrence in related literature, green indicates keywords with medium intensity, and blue or purple indicates keywords that appear less frequently. The keywords "flood risk", "regression model", and "disaster mitigation" are the most dominant (coloured yellow), indicating that the research around them is widely conducted. Other frequently appearing keywords are "insurance system", "insurance", "optimization", and "climate disasters". These keywords are spread across several sub-fields, reflecting research in different aspects of insurance. This visualization shows that insurance and natural disaster risk research is a significant topic. However, there is no research on the probability of ruin of disaster insurance companies.

Based on Figures 2, 3, and 4 presented in this study, it is clear that topics related to insurance systems, disaster risk, and mitigation have remained a major focus in scientific literature in recent years. However, the results of the visualization of co-occurrence–word relation map, visualization of co-occurrence–year, and Visualization of co-occurrence– density map confirm that there has been no explicit study addressing the probability of ruin or disaster insurance in the context of financial risk management for insurance companies. This indicates a significant gap in the literature, which could be addressed by a probabilistic analysis-based ruin model approach for insurance companies facing disaster risks.

The bibliometric analysis in this study highlights the research that needs to be conducted to provide important theoretical and practical contributions to the insurance and natural disaster risk system in Indonesia. Based on a theoretical perspective, this study opens up new horizons in the development of bankruptcy risk models for insurance companies using a quantitative approach that has not been widely studied in previous literature. The practical perspective, the findings of this study are expected to provide insights to regulators, insurance companies, and policymakers in developing long-term financing and risk mitigation strategies to ensure the sustainability of the disaster insurance system. Thus, this study not only fills a gap in the literature but also strengthens the scientific foundation for data-driven decision-making in the disaster insurance sector.

3.4 Description of Articles Result

In this section, the nine articles selected are articles from various countries that are often affected by disasters that harm the country, such as Purwandari et al. [33] and Kalfin et al. [14] who developed the determination of natural disaster insurance premiums in Indonesia. Bleemer & van der Klaauw [34], Bhattacharyya & Hastak [35], and French & Kousky [36] conducted research in the United States by discussing natural disaster insurance due to Hurricane Katrina, the relationship of flooding to natural disaster insurance, and assessing the role of disaster insurance in strengthening community resilience to climate disasters. Duqi et al. conducted research in the United Kingdom that discussed the structure of the banking market affecting economic recovery after natural disasters [37]. Pothon et al. conducted research in France by focusing on the factors that influence people's decisions to buy earthquake insurance in California [15]. Ma & Jiang conducted research in China with a discussion of developing a special risk management model using a partnership approach between the government, insurance companies, and communities [16], and Ohori developed a financial model that considers disaster-related risks and the financial condition of railway companies in Japan [13]. Based on the country of affiliation, the authors are countries vulnerable to natural disasters. The following is a description of 9 articles based on affiliation, and the number of citations shown in Table 3.

Table 3. Article description based on Affiliation, Database, and Number of Citations.

Author(s)	Affiliation	Database	Number of citations
Ma & Jiang [16]	China	Scopus, ScienceDirect, Dimensions	7
Pothon et al. [15]	France	Scopus, Dimensions	15
Ohori [13]	Japan	Scopus	0
Bleemer & van der Klaauw [38]	US	Scopus, ScienceDirect, Dimensions	13
Duqi et al. [36]	UK	Scopus, ScienceDirect, Dimensions	21
French & Kousky [35]	US	Scopus, Dimensions	1
Kalfin et al. [14]	Indonesia	Scopus, Dimensions	2
Bhattacharyya & Hastak [34]	US	Scopus, ScienceDirect, Dimensions	3
Purwandari et al. [32]	Indonesia	Scopus, Dimensions	1

Table 3 shows nine papers published in various countries and spread across three search databases. Each article of the nine articles used as study material has different citations, where the most cited is research conducted by Duqi et al. [36] with a total of 21 citations, research Pothon et al. [15] with a total number of citations of 15, and research Bleemer & van der Klaauw [37] with as many as 13 citations. Furthermore, the following is a description of 9 articles related to the article's purpose and the year of publication used as study material, which is shown in Table 4.

Table 4. Article description based on purpose and the year of publication.

Author(s)	Purpose	Years
Ma & Jiang [16]	To balance insurance supply and demand and improve market stability, create a Pareto-based risk optimization model within the GMPP (Government, Market, and Public Partnership) framework.	2018
Pothon et al. [15]	Analyse the factors of low earthquake insurance participation in California, focusing on the influence of premium price and risk perception.	2019
Ohori [13]	Developed mathematical models to calculate the probability of hurricane and flood damage, and provided risk financing strategies for railway businesses.	2019
Bleemer & van der Klaauw [38]	Examined the long-term impact of the federal disaster insurance programme on the economic well-being of individuals affected by Hurricane Katrina.	2019
Duqi et al. [36]	Analysed how the banking market structure affects regional economic recovery after natural disasters.	2021
French & Kousky [35]	Examine the effect of catastrophe insurance on community resilience and develop a research agenda to assist local policies in improving adaptation to disaster risk.	2023
Kalfin et al. [14]	Develop an insurance premium model based on the Compound Poisson with Jumps and cross-subsidisation. This model would take into account disaster risk and economic growth to create fairer premiums across Indonesia.	2023
Bhattacharyya & Hastak [34]	Identifying causal relationships between flood risk factors and insurance payouts to improve flood risk reduction strategies in the US.	2024
Purwandari et al. [32]	Developed a natural disaster insurance premium determination model using Black-Scholes, considering cross-subsidisation and economic growth to generate affordable and fair premiums.	2024

Table 4 explains that research has been done on the problems faced by each country with different risk mitigation objectives. For example, research Ma & Jiang [16] and Duqi et al. [36] conducted research with a focus on balance in insurance market stability, Pothon et al. [15] focused on the effect of premium prices and risk perceptions, Ohori [13] developed a mathematical model to calculate the probability of destruction due to storms and floods in the railway business, French & Kousky [36] examined the effect of disaster insurance on the risks caused, Kalfin et al. [14] and Purwandari et al. [33] developed an insurance premium model for natural disaster risk, and Bhattacharyya & Hastak [35] focused on the relationship between flood risk factors and insurance payments in improving flood risk reduction strategies in the US. Then the following is a description of articles to answer RQ1, RQ2, and RQ3 that have been set, where the answers are shown in Table 5 related to Description of Articles Result based on Variables, Distribution, and Methods used in nine articles.

Table 5. Article Description based on Affiliation, Database, and Number of Citations.

Author(s)	Variables	Distribution	Method
Ma & Jiang [16]	Disaster frequency, Initial risk value, loss, Insurance premium, and Transaction cost.	Pareto Distribution	Pareto Optimization, and Stochastic Model (GMPP framework)
Pothon et al. [15]	Earthquake insurance participation rate, risk perception, and insurance premium	-	Expected utility model and Linear regression
Ohori [13]	Probability of destruction, aggregate loss in hurricane disaster, and derailment in the railway business	Poisson Distribution and Exponential Distribution	Probability of destruction model, and Statistical model of loss aggregation
Bleemer & van der Klaauw [38]	Home ownership rate, Bankruptcy rate, Population mobility, Consumption rate, Credit status, and Impact of federal programmes on income	Panel Data Distribution of Credit Reports	Spatial regression-discontinuity and difference-indifferences

Duqi et al. [36]	Banking market structure (Lerner index), Real estate credit, Per capita income, Economic growth, and Disaster data	Geographic Distribution with time series	Triple-difference and Panel data econometric analysis
French & Kousky [35]	Disaster insurance and Community resilience	-	Systematic literature review (SLR) with the PRISMA method
Kalfin et al. [14]	Frequency of disaster events, Economic losses, Economic growth rate, and Disaster potential index	Poissn Distribution and Weibull Distribution for Losses	Compound Poisson with Jumps and Cross-Subsidy System
Bhattacharyya & Hastak [34]	Flood exposure, Infrastructure vulnerability, Social vulnerability, Number of residential houses, Receipt of public assistance, and Flood insurance claims data	Log-linear Distribution	Mixed Effects Regression
Purwandari et al. [32]	Frequency of disaster events, Economic losses, Disaster potential index, and Economic growth rate	Normal Distribution for Losses	Black-Scholes Model, Compound Poisson with Jumps, and Collective Risk Model.

Table 5 shows the diversity of variables used by each article under review. In general, the variables used on average use natural disaster event variables, such as Ma & Jiang [16], Kalfin et al. [14], Bhattacharyya & Hastak [35], Purwandari et al. [33] using the primary variable is the frequency variable of natural disaster events, Pothon et al. [15] and French & Kousky [36] using disaster insurance variables as the primary variable, Ohori [13] using the primary variable is the railway business company in Japan, and Bleemer & van der Klaauw [34] using occupancy and occupation mobility as the primary variable. Then the methods used by the nine papers are very diverse and different. Ma & Jiang [16] uses Pareto Optimization method, and Stochastic Model (GMPP framework) using Pareto distribution, Pothon et al. [15] uses Expected utility model and Linear regression method, Ohori [13] uses destruction probability model, and Loss aggregation statistical model, with Poisson distribution and Exponential distribution, Bleemer & van der Klaauw [34] focuses on Spatial regression-discontinuity and Difference indifferences with Panel data distribution based on credit report, Duqi et al. [37] used Triple-difference method and Panel data econometric analysis and Geographical distribution with time variable as the distribution, in contrast to French & Kousky [36] conducted his research Systematic Literature Review (SLR) with PRISMA method, Kalfin et al. [14] used Compound Poisson with Jumps and Cross-Subsidy System with Weibull distribution for losses, Bhattacharyya & Hastak [35] used Mixed Effects Regression method with log-linear based distribution, and Purwandari et al. [33] used Black-Scholes Model, Compound Poisson with Jumps, and Collective Risk Model with Normal distribution for losses.

3.5 Literature Gap Analysis and Future Research

Research on insurance and catastrophe risk has grown significantly, with various approaches used to manage natural disaster risk in different sectors. Some of the above analyses show that different approaches have been applied to modelling risk, ranging from Pareto optimization for insurance markets to probability of destruction-based models for specific sectors such as transportation. Various distributions, such as Pareto, Poisson, and log-linear, capture the complex dynamics of risks and losses. However, these studies tend to focus on specific regions or sectors, leaving an opportunity to develop more holistic and applicable models in various contexts.

Developing better Disaster insurance models requires integrating multidisciplinary approaches to cover a broader range of variables and factors. For example, while probability models such as the one used by Ohori [13] are instrumental in the transport sector, they can be extended to consider risks across sectors to provide a more inclusive approach. Similarly, cross-subsidy-based models, such as the one developed by Purwandari et al. [33] can be adapted to provide more equitable financial solutions, particularly for low-income communities vulnerable to disaster impacts.

Thus, based on the discussion, several developments are based on the research conducted. The following are development recommendations that can be carried out in the future, while answering RQ4 are as follows:

1. Based on the review of papers used, all papers focus more on the impact of losses by natural disasters on infrastructure damage and the impact on the community's economy. There is no modelling of ruin probability in disaster insurance companies.
2. Disaster events cannot be predicted when they will occur. Therefore, insurance companies need a tool to model the surplus to determine the reserve amount of funds available to them. A sufficient surplus allows the insurance company to deal with unexpected claims.

3. Because there are so many types of disaster events, insurance companies cannot predict what disasters will occur. When an insurance company experiences ruin due to a natural disaster event, the company needs to know the amount of shortfall it experiences when ruin occurs. Therefore, disaster insurance companies need tools to model deficits when ruin occurs.
4. When was the surplus model modelled before ruin and the deficit model after ruin in disaster insurance companies? Then the probability of ruin in insurance companies can be predicted and mitigated. The ruin probability model in disaster insurance companies is essential, given that Disaster events can occur at any time. So, it is necessary to model the probability of ruin in disaster insurance companies to mitigate the occurrence of ruin and the risk of loss for policyholders.
5. In addition, this study recommends future research on modelling the moments before ruin and post-ruin, focusing on the recovery process in disaster insurance companies in Indonesia.

4. CONCLUSION

This study reviews articles systematically, by providing a Systematic Literature Review (SLR) presentation. This research uses nine articles that match the research topic collected based on filters from the Scopus, Science Direct, and Dimensions databases. This research uses a Bibliometric Analysis approach with the support of VOSviewer software, utilizing the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method. The results of this study indicate that research related to insurance and risks due to natural disasters has been carried out in areas that are often affected by natural disasters. However, all of these articles focus more on the impact of natural disasters and the impact of losses due to natural disasters on infrastructure damage and the impact on the community's economy. There has been no research discussing models that focus on the probability of ruin or disaster insurance in the context of financial risk management for disaster insurance companies. Therefore, this research is necessary for future development of ruin risk models for insurance companies. This study is expected to serve as a reference for further research on the probability of ruin in disaster insurance and to make a significant contribution to the formulation of policies at disaster insurance companies in Indonesia.

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