

## Responsibility and Future of Insurance Industry

### Summary

Extreme weather events pose risks. Insurance helps transfer risk and protect property owners. However, post-disaster, insurers' financial stability is tested. Balancing reliable risk transfer and insurer solvency is a challenge.

Several models have been established: Model I: Extreme Weather System Determination; Model II: **Disasters-Insurance Relationship** Coupling Analysis; Model III: **Regional Risk Assessment** Model; Model IV: Multi-Criteria Community Development Strategy.

Before modeling, we analyzed extreme weather frequency and insurance claims, which are key for risk prevention. We obtained relevant, reliable data through official channels..

For Model I: This model organized the data and then applying Entropy Weight Method (EWM) and Analytic Hierarchy Process (AHP) to determine extreme weather weight. The Monte-Carlo simulation was utilized to approximate event probabilities. Using **Fitting and Predicting Algorithm** to model the trend, predict quantities and probabilities for 2030, 2040, and 2050 with compiling tables of five main extreme weather events from 1900 to 2023.

For Model II: This model analyzes the relationship between natural disasters and insurance purchases. It uses a **Logistic function** to forecast insurance purchases based on extreme weather probabilities, computes insurance companies' profitability and sets the insurance coverage premium range as well. Applications in Germany and the U.S. show that actual insurance purchases often miss predictions, suggesting potential financial risks for insurers in areas with rising extreme weather events, the business allocation of insurance companies was requested.

For Model III: This model uses a **Fuzzy Comprehensive Evaluation** method to assess the risk of construction and development in a region. It considers factors such as extreme weather occurrence, infrastructure quality, and population density. The model normalizes these factors, applies membership functions, and uses a fuzzy relational matrix to derive a comprehensive risk assessment.

For Model IV: This model is a **Strategy-making model** for community development, focusing on historical and cultural architecture. It outlines the process of acquiring decision-making information, assembling it, and proposing recommendations. The model uses three key factors: extreme weather events, infrastructure quality, and population density. A case study of the Northern Song Dynasty Imperial Mausoleum in Gongyi, China, is provided to illustrate the model's application.

Finally, we wrote a letter to make future plans, timelines, and cost recommendations for community leaders.

**Keywords:** Property Insurance, Disasters-Insurance Relationship, Regional Risk Assessment

# Content

<b>1 Introduction .....</b>	<b>3</b>
1.1 Problem Background .....	3
1.2 Restatement of Problem .....	3
1.3 Overview of Our Work .....	4
<b>2 Assumptions and Justifications .....</b>	<b>4</b>
<b>3 Notations and Descriptions .....</b>	<b>5</b>
<b>4 Model Preparation .....</b>	<b>6</b>
4.1 Data Collection .....	6
4.2 Data Pre-Processing .....	6
<b>5 Model I: Extreme Weather System Determination .....</b>	<b>7</b>
5.1 Probability Evaluation Model .....	7
5.2 Probability Fitting and Predicting Model .....	10
<b>6 Model II: Disasters-Insurance Relationship Coupling Analysis .....</b>	<b>12</b>
6.1 Model Description .....	12
6.2 The Establishment of Model .....	13
6.3 Application of Model I and Model II .....	13
<b>7 Model III: Regional Risk Assessment .....</b>	<b>15</b>
7.1 Fuzzy Comprehensive Evaluation .....	15
7.2 Model Application .....	17
<b>8 Model IV: Multi-Criteria Community Development Strategy .....</b>	<b>18</b>
8.1 Multi-attribute decision analysis model .....	18
8.2 Model Application: .....	19
<b>9 Model Evaluation .....</b>	<b>20</b>
9.1 Strengths .....	20
9.2 Weaknesses and possible Improvements .....	20
<b>10 Conclusion .....</b>	<b>21</b>
<b>Recommendations and Proposals Letter for Henan Community .....</b>	<b>22</b>
<b>References .....</b>	<b>23</b>
<b>AI Report .....</b>	<b>24</b>

# 1 Introduction

## 1.1 Problem Background

Carefully tended farmland can be swiftly eroded in the face of sudden floods, and expensive factories can be destroyed in the aftermath of a hurricane. People find themselves powerless in the wake of extreme weather events, and the devastation wrought by such catastrophes significantly diminishes individuals' risk-taking abilities while making investors increasingly cautious.

To mitigate these risks and enhance resilience, catastrophe insurance offered by insurance companies has emerged as an excellent mechanism for transferring risk and safeguarding investors.<sup>[1]</sup> However, this protective shield comes with its own set of challenges. Insurance companies, grappling with immense pressure on their capital chains in the aftermath of catastrophic events, find themselves struggling for financial stability.<sup>[2]</sup>

Finding a balance that allows insurance to be a reliable means for individuals to transfer risk without pushing insurance companies to the brink of closure due to losses becomes both an opportunity and a formidable challenge for the insurance industry.



**Figure 1: What protects us in extreme weather?**

## 1.2 Restatement of Problem

Insurance industry is a comprehensive industry with multi-factors consideration and multi-objectives planing. In order to ensure the sustainable development of the insurance industry, through in-depth analysis and research on the background of the problem, combined with some requirements, the restatement of the problem can be expressed as follows:

- **Objective 1:** Determine the occurrence quantities and the probability of extreme weather occurrence, prepare for the building of follow-up model.
- **Objective 2:** Based on the probability of extreme weather, ensure that the insurance company can make profits and that the risk of property owners can be effectively transferred. Judge that whether the insurance company should underwrite policies, and clarify the conditions of both sides to underwrite the insurance policy.

- **Objective 3:** Develop a comprehensive evaluation model to evaluate whether a place is buildable and evolvable.
- **Objective 4:** Construct a preserve model to provide community leaders with decision support on building protection, and provide accurate and scientific suggestions on building protection measurements
- **Objective 5:** Consider the result obtained above, provide a one-page letter to community.

### 1.3 Overview of Our Work

Based on comprehensive review, our work mainly includes the following:

- **Model I: Extreme Weather System Determination for Objective 1**  
Applying methods: EWM, AHP, Fitting and Predicting algorithm.
- **Model II: Disasters-Insurance Relationship Coupling Analysis for Objective 2**  
Applying methods: Sigmoid Function, Disaster-Insurance Coupling Analysis.
- **Model III: Regional Risk Assessment Model for Objective 3**  
Applying methods: FCE.
- **Model IV: Multi-Criteria Community Development Strategy for Objective 4**  
Applying methods: Multi-Attribute Decision Analysis.
- **A one-page letter for community for Objective 5**

In summary, the whole process can be shown in the following Figure 2:

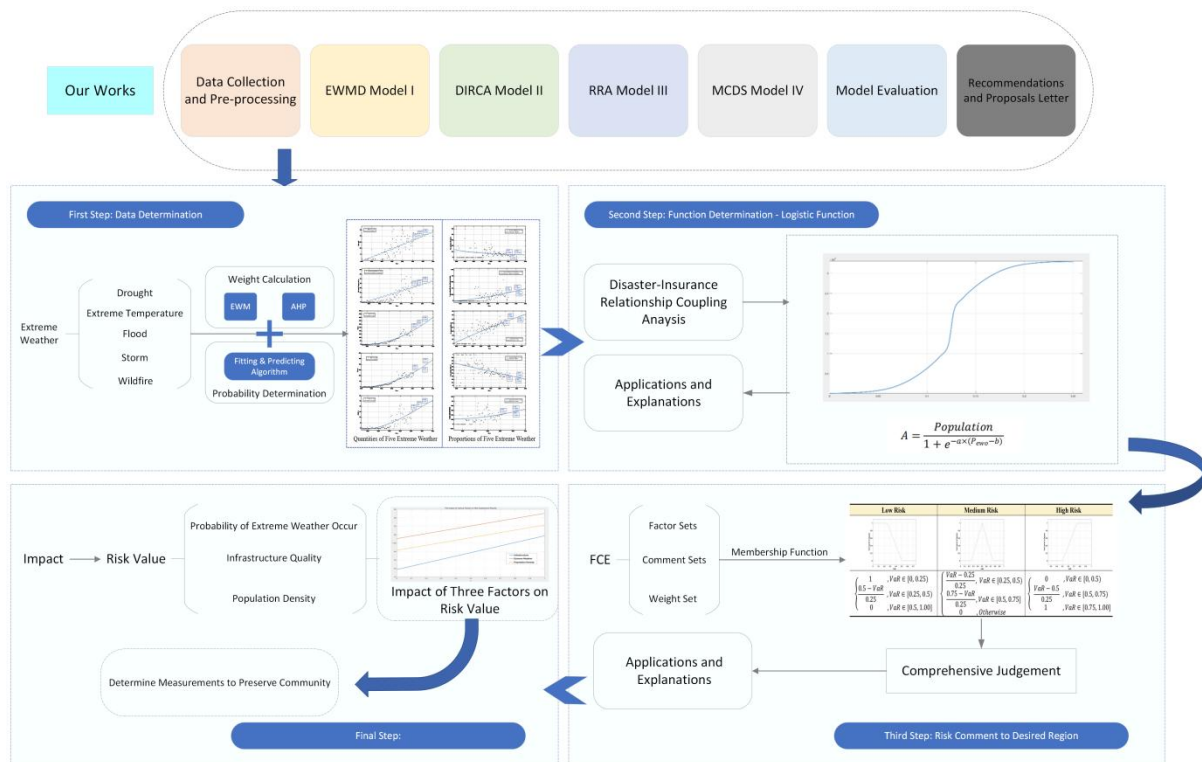


Figure 2: Overview of Our Works

## 2 Assumptions and Justifications

Limited by a variety of natural and man-made influences, our team has made assumptions about a number of conditions to simplify problems, each assumption is closely followed by its corresponding justification:

- **Assumption 1: Sales of catastrophe insurance is not related to the premium that needs to be spent.**

**Justification 1:** The main factor driving the increase in the number of catastrophe insurance purchasers is people's increased awareness of risk and their demand for risk avoidance. This demand for risk aversion is not created by lower price but created continuously in the situation of economic growth.

- **Assumption 2: Profitability of catastrophe insurance ranges from 1.5% to 2%.**

**Justification 2:** According to Mary Hall's research, the net profit margin is 16.33% for general property insurance and 4.99% for health and life insurance catastrophe<sup>[3]</sup>. Considered the devastating natural disasters caused by extreme weather, those insurance products as a public service program that encourages investment and transfers risk are more favoured, so we keep the profit margins between 1.5% and 2% to ensure that insurance companies can make a profit and the premiums for insurance is affordable for property owners.

- **Assumption 3: Each insurance company already has the ability to price property.**

**Justification 3:** The devastation of a catastrophe requires that the insurance company have sufficient funds to fulfill the contract, so that the property owners to sign the agreement with confidence.

- **Assumption 4: The data collected can be considered accurate and reliable.**

**Justification 4:** We obtained data from the official website and reference books with high accuracy. All of websites and articles we used to search data are well represented below.

## 3 Notations and Descriptions

The key mathematical notations used in this paper are listed in Table 1 below:

Symbol	Data Resources
$P_{ewo}$	Probability of extreme weather occurrence
$P_{5/ewo}$	Matrix of the probability of five different extreme weather occurrence under the occurrence of extreme weather
$P_{5ewo}$	Matrix of the probability of five different extreme weather occurrence
$I$	Company Income
$P_{num}$	Number of purchasers
$PCI$	Premium corresponding to the value of the insured object
$VI$	Value of the insured object

**Table 1: Notations Used in Our Paper**

## 4 Model Preparation

### 4.1 Data Collection

Since this problem does not provide us any relevant data, finding accurate, effective and credible data becoming one of the most essential challenges. By our initial analysis of this mathematical model, we need to search for related information about the extreme weather events such as the time, location and frequency.

The policy and strategy of insurance in America and Germany was consulted, and various data in drafting our insurance model were founded. In order to express our gratitude and respect to the website who collects these data, the main data resources including data websites are shown in the following Table 2.

Data Description	Data Resources	Types
Events Details	<a href="https://www.emdat.be/">https://www.emdat.be/</a>	Mixed
Extreme Weather Standards	<a href="https://www.wcrp-climate.org/">https://www.wcrp-climate.org/</a>	Ecology
Basic Insurance Data	<a href="https://data.worldbank.org.cn/">https://data.worldbank.org.cn/</a>	Economy
Insurance Policy and data	<a href="https://zh.wikipedia.org/wiki/Wikipedia/">https://zh.wikipedia.org/wiki/Wikipedia/</a>	Economy
Map and Image	<a href="https://www.mapbox.com/">https://www.mapbox.com/</a>	Image
Country's Population	<a href="https://data.worldbank.org.cn/">https://data.worldbank.org.cn/</a>	Population
Relevant City Data	<a href="https://tjj.fujian.gov.cn/xxgk/njgb/tjnj/">https://tjj.fujian.gov.cn/xxgk/njgb/tjnj/</a>	Mixed

**Table 2: Data Source Collation**

### 4.2 Data Pre-Processing

Because the data we obtained is all statistics when an event have occurred over the years, there are exception value existed in data. To reduce the impact of these strange sample data on the entire model, we are required to process these data through standardized processing. The original matrix is expressed as  $X = [X_1, X_2, X_3, \dots, X_n]$ , utilizing the standardized processing method as followed:

$$Y_i = \frac{X_i}{\sqrt{\sum_{i=1}^n X_i^2}} \quad (1)$$

Then we obtained the standardized matrix  $Z = [Z_1, Z_2, Z_3, \dots, Z_n]$ , which can be used in latter calculations.

## 5 Model I: Extreme Weather System Determination

Considering the **Objective I** proposed above, our paper established a model used to determine the detail of the probability of the extreme weather event occur among the whole world. **Firstly**, we organized our data and use entropy weight method (EWM) and analytic hierarchy process (AHP) to determine the weight of extreme weather, applying the idea of Monte-Carlo simulation, we determined the probability of extreme weather occurrence. **Secondly**, we arrange the data we have collected and compiled them a table of the number of occurrences of the five main extreme weather events per year from 1900 to 2023, then we use fitting algorithm to fit the trend of the frequency and probability of events occurring over a hundred years. **Finally**, we utilized the prediction model to predict the frequencies and probability of the five main extreme weather events in 2030, 2040, 2050. All the simulation results verified the effectiveness and rationality of our model.

### 5.1 Probability Evaluation Model

There are various extreme weather events occur in the world, it is not realistic and practical to evaluate all of them. Besides, the influencing factors of different extreme weather is different. In these model, we selected five main extreme weather: Flood, Drought, Extreme Temperature, Wildfire and Storm; And for each of them, we selected five evaluation indicators.

#### 5.1.1 Entropy Weight Method

As an objective weighting method, EWM determines the weight of the indicator based on the data provided of each indicator.

Organizing the data, we have the following specific definitions:

$$\begin{aligned}
 Drought_{sum} &= \sum_{i=1}^n Drought_{num} \\
 Extreme\ Temperature_{sum} &= \sum_{i=1}^n Extreme\ Temperature_{num} \\
 Flood_{sum} &= \sum_{i=1}^n Flood_{num} \\
 Storm_{sum} &= \sum_{i=1}^n Storm_{num} \\
 Wildfire_{sum} &= \sum_{i=1}^n Wildfire_{num}
 \end{aligned}$$

Where :

- $Drought_{num}$ ,  $Extreme\ Temperature_{num}$ ,  $Flood_{num}$ ,  $Storm_{num}$ ,  $Wildfire_{num}$  represents the number of extreme weather occurrence.
- $Drought_{sum}$ ,  $Extreme\ Temperature_{sum}$ ,  $Flood_{sum}$ ,  $Storm_{sum}$ ,  $Wildfire_{sum}$  represents the total number of extreme weather occurrence.

Normalized and standardized all indicators from the equation (1) above to obtain the standardized matrix:  $Z = [Z_{Drought}, Z_{Extreme\ Temperature}, Z_{Flood}, Z_{Storm}, Z_{Wildfire}]$ .

- Calculate the probability matrix of  $i_{th}$  sample under  $j_{th}$  item:

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^n Z_{ij}} \quad (2)$$

- Calculate the information entropy of each type of extreme weather:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^n P_{ij} \ln (P_{ij}) \quad (3)$$

- Calculate the weight of each type:

The greater the information entropy  $e_j$ , the less the information of the extreme weather has, furthermore, the less its weight.

$$d_j = 1 - e_j \quad (4)$$

$$W_j = \frac{d_j}{\sum_{j=1}^n d_j}, \sum_{j=1}^n W_j = 1, W_j \in [0, 1] \quad (5)$$

Based on the above EWM determination, we can define the weight of the five extreme weathers:

$$W = [0.0644, 0.0517, 0.4711, 0.3754, 0.0374]$$

each term of this matrix corresponds to the above five extreme weathers.

Applying the idea of Monte-Carlo simulation: For a considerable amount of time, the probability of an event occurring can roughly estimated as the proportion of its occurrence times to the total number. We can roughly obtain that: When an extreme weather occur, the probability of the occurrence of five type of extreme weather event is equal to the weight of them. Therefore, we can determine the probability:

$$P_{5/ewo} = [0.0644, 0.0517, 0.4711, 0.3754, 0.0374]$$

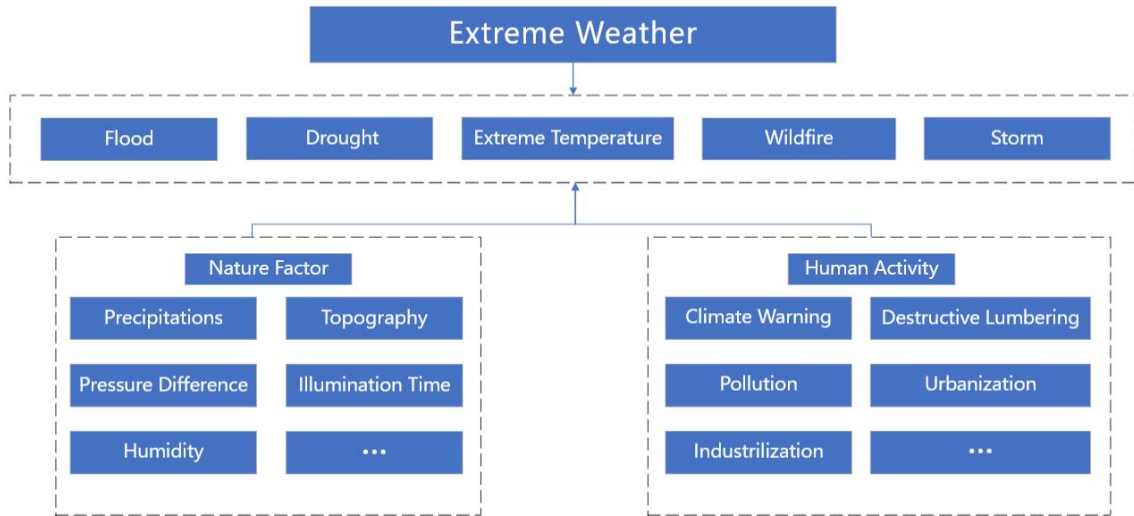
### 5.1.2 Establishment of Model Structure

In order to evaluate the probability of extreme weather occurrence, we use AHP method with establishing a three-layer evaluation model.

- Layer III: Influencing factors which separated into nature factors and human activities, which are used to evaluate the weight of five extreme weather.
- Layer II: Five types of extreme weather, because the influencing factors of different extreme weather is different, we select five factors from Layer III for the five extreme weather to evaluate its probability.



- Layer I: The probability of extreme weather occurrence is correspond to the probability of the five extreme weather.



**Figure 1: Flowchart of Three-Layer Hierarchy Structure**

### 5.1.3 Calculation for Probability Model

Starting from the second layer of the structure, we constructed a pairwise comparison matrix using pairwise comparison method with a comparison scale from 1 to 9. The pair comparison matrix  $A$  is defined as below:

$$A = (a_{ij})_{n \times m}, \quad a_{ij} > 0, \quad a_{ji} = \frac{1}{a_{ij}} \quad (6)$$

After obtaining the weight of extreme weather, we are required to test the consistency of our matrices. In this case, the consistency index ( $CI$ ), mean random consistency index ( $RI$ ) and consistency ratio ( $CR$ ) are required to calculated as follows:

$$\begin{cases} CI = \frac{\lambda_{max} - n}{n - 1} \\ CR = \frac{CI}{RI} \end{cases} \quad (7)$$

Where  $n$  represents the order of the comparison matrices,  $\lambda_{max}$  represents the maximum eigenvalue of matrices. Finally, we utilize MATLAB to calculate and find the final  $CR < 0.1$ , which represents that the consistency of the judgement matrix is acceptable.

Though correlation searching, the probability of a small probability event is less than 5%<sup>[4]</sup>. By our calculation, we finalist obtain the probability of extreme weather occurrence and the probability of extreme weather not occur is [0.0928, 0.9072] which is approximately satisfied our expectations. Hence we can define the probability of extreme weather occurrence is  $P_{ewo} = 0.0928$ .

In order to obtain the probability of five extreme weather occurrence  $P(AB)$ , we can apply the following formula:

$$P_{5/ewo} = \frac{P_{5ewo}}{P_{ewo}} \quad (8)$$

Finally we can get the Table 1 below:

Situation	Weight	Event Type	Weight	Probability
Disaster Not Occur	0.9072	None	1	0.9072
Disaster Occurring	0.0928	Drought	0.0644	0.0060
		Extreme Temperature	0.0517	0.0048
		Flood	0.4711	0.0437
		Storm	0.3754	0.0348
		Wildfire	0.0374	0.0035

**Table 1: Weight and Probability of Extreme Weather**

## 5.2 Probability Fitting and Predicting Model

As mentioned in the **Objective I**, we are required to find the relationship between the quantity of extreme weather occurrence and time. Therefore, our paper established the fitting model using MATLAB.

### 5.2.1 Fitting Algorithm

As a data based method, we organized the quantity of occurrences of the five types of extreme weather events from 1900 to 2023, and collect our data into a table, then we take time as the independent variable, the number of occurrences as the dependent variable. Putting these point into MATLAB, we can finally identified the five types of extreme weather with their respective relationship between quantity of occurrences and time.

Furthermore, with the quantity data, we found their respective proportion to the total quantity from 1900 to 2023 by standardize the data from the way of data pre-processing above. In this way, we take time as the independent variable, the proportion of each extreme weather as the dependent variable. Using MATLAB, found the five types of extreme weather with their respective relationship between proportion and time.

### 5.2.2 Predicting Algorithm

In order to predict the quantity of extreme weather occurrence, we utilized the relationships we fitted from fitting algorithm above, obtained the predicted data in 2030, 2040, 2050.

Based on the mathematical definitions above, we have designed a MATLAB program for this fitting and predicting model as follows:

**Algorithm:** Fitting and predicting of the quantity and proportion of extreme weathers

**Input:** Time, Quantity, Proportion;

**Initialize** the start value, upper bounds, lower bounds, and some other options;

According to time, quantity, proportion, draw the position of each point;

According to the chart, set up fit type as 'Nonlinear LeastSquares';

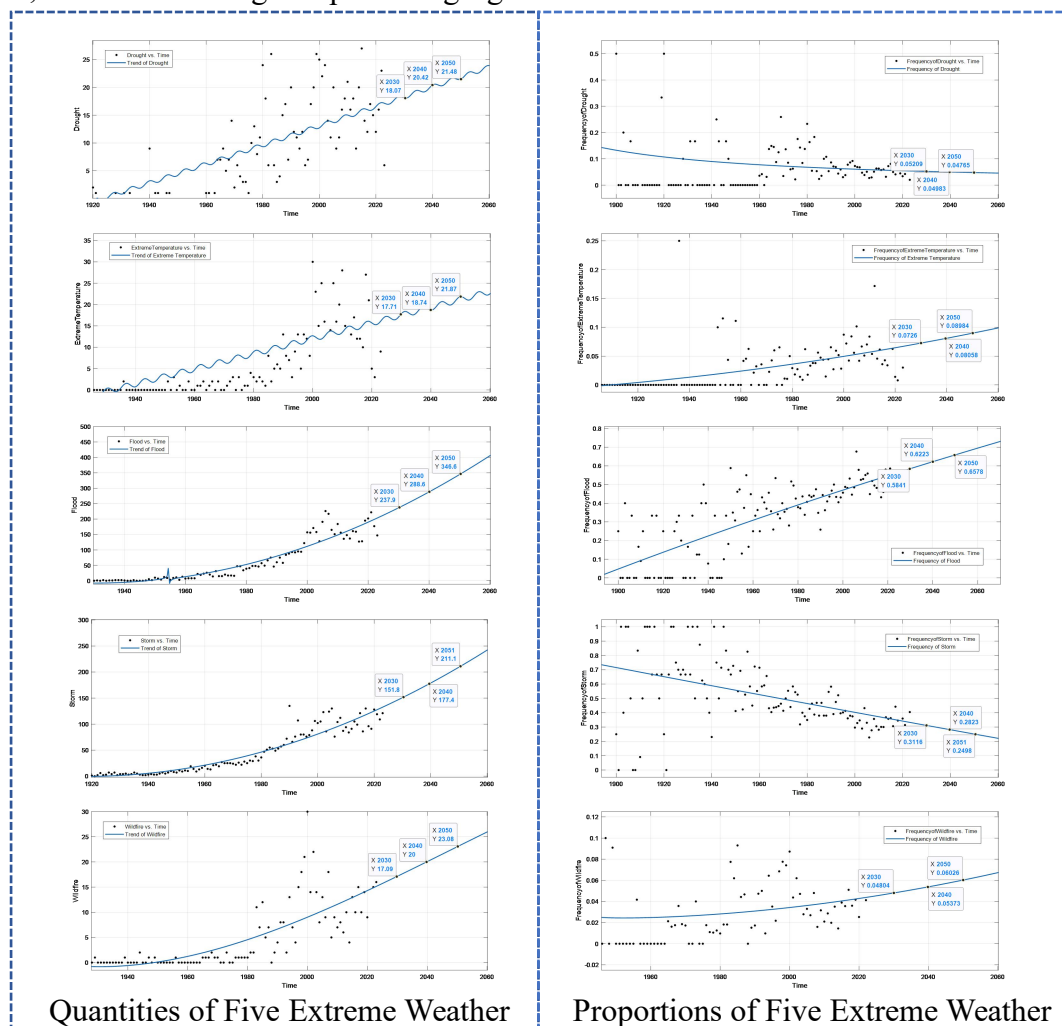
Fit model to the data automatically;

**Plot** fit function with data;

**Label** axes for each graph;

**Mark** predicted data in 2030, 2040, 2050 using data cursor;

Ultimately, we obtained and presented five quantity figures and five proportion figures with over one hundred years fitting and fifty years predicting and marked the data in 2030, 2040, 2050. The Fitting and predicting figures are shown below:



**Figure 2: Quantities and Proportions of Five Extreme Weather**

### 5.2.3 Results Analysis

From the fitted and predicted figure, we can obviously observe that the quantities of the occurrence of the five types of extreme weather is steadily growing, among these five, the flood has the highest number and the rapidest speed of increasing, which means that the flood dominated the occurrences of extreme weather. In other words, when an extreme weather event occurs, the occurrence probability of flood is highest, which is the same with our expectation in Table 1.

## 6 Model II: Disasters-Insurance Relationship Coupling Analysis

### 6.1 Model Description

In this model, we borrowed the results from previous model which predicted the probability of extreme weather occurrence around the world, and combined them with reasonable assumptions to form a function of the probability of extreme weather events and the number of people who buy insurance. Because the number of insurance purchases can not exceed the current local population, we applied the Logistic equation. The relationship between probability of extreme weather and the number of insurance purchasers based on the Logistic function is shown below:

$$A = \frac{\text{Population}}{1 + e^{-a \times (P_{ewo} - b)}} \quad (9)$$

In this formula, the  $a$  and  $b$  are the impact parameters decided on the local situations. We need input the data of local population and number of current insurance purchases and then the values of parameters  $a$  and  $b$  are obtained to match the local situation using the code we have given for fitting the parameters, which further yields the predicted values of the number of local insurance purchases.

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**Algorithm:** Fitting Local Situation by Determine  $a$  and  $b$

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**Input:** Probability, number of purchasers, population;

**Output:**  $a$ ,  $b$ ;

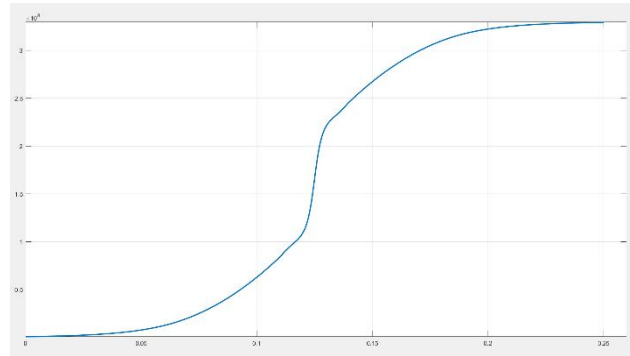
Determine the axis length and the range of  $a$ ,  $b$ ;

According to input, fit the equation (9);

**Obtain the value of  $a$ ,  $b$ ;**

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The figure below shows an ideal image of the Logistic equation.



**Figure 3: An ideal image of the Logistic Equation**

## 6.2 The Establishment of Model

Recall our assumption, the range of profitability was defined to from 1.5% to 2%, therefore we can list the following relationship of the insurance company:

$$I = P_{num} \times PCI \quad (9)$$

$$E = VI \times P_{ewo} \quad (10)$$

$$Profit = I - E = P_{num} \times PCI - VI \times P_{ewo} \quad (11)$$

Based on the profitability requirement, we can write inequalities to determine the extent to which the insured value corresponds to the insured price:

$$1.015 \times E \leq P_{num} \times PCI \leq 1.02 \times E \quad (12)$$

Combining the probability of extreme weather and modeling the number of insurance purchasers, we can obtain the value of  $P_{num}$  through using equation (12).

At this point, all the parameters that fit the special case have been derived, except for the value of the insured object, which is an unknown quantity.

Then, based on each insurance company's own property pricing model, the value of the insured property is calculated and brought into this model to obtain the range of premiums that the insurance company should charge.

To determine whether a policy is covered, all that is required is that the property owner accepts a premium within known limits, and the parties can reach an agreement on coverage and the insurance company will underwrite the policy. Conversely, the policy is not covered.

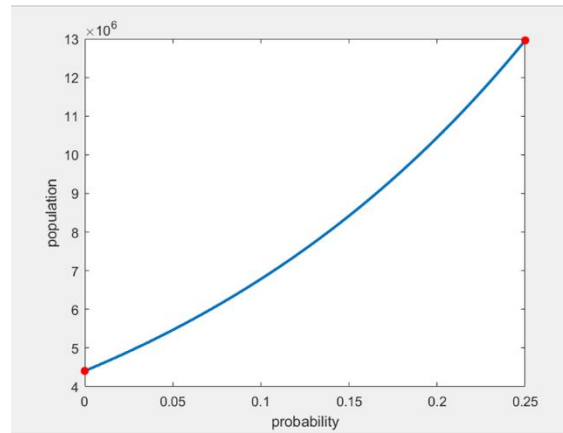
## 6.3 Application of Model I and Model II

Using Germany in Europe and the United States in North America as examples, we use the model we built above to make judgments about whether policies are written in both places.

### 6.3.1 Flood Event in Germany in Bayern in 2005

Based on the probability of occurrence of extreme weather in 2005, the model was used to calculate the number of people purchased catastrophe insurance in Bayern in 2005  $P_{num} = 6,148,409$ . The actual number of  $P_{num}$  is 4,405,600 which is calculated by the population

proportion of Bayern to the whole population in Germany. The model has been explained in detail above and we have obtained the function values based on the model and drawn the complete image. The actual number of insurance purchases did not meet expectations.



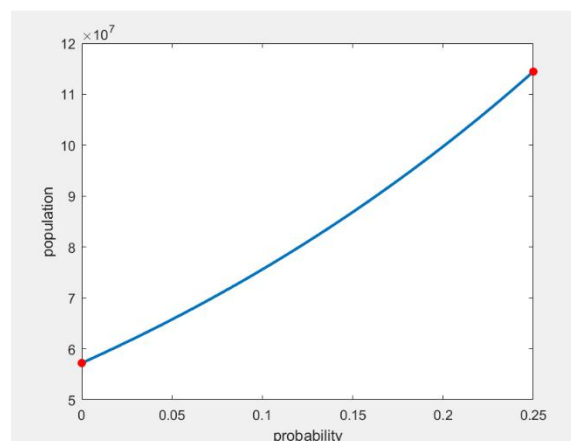
**Figure 4: Expectation Value of  $P_{num}$  in Flood Event**

### 6.3.2 Hurricane Event in US in 2021

For the year 2021 in the United States, a hurricane has swept through 12 states, including North Carolina, Oklahoma, and others.

According to the first model, we calculate that the probability of extreme weather in the United States in 2021 is: 11.08%. According to the second model, the number of people purchased catastrophe insurance in 12 states in US in 2021  $P_{num} = 70,912,111,000$ . Combining the actual losses with the insurance claims data, it is estimated that about 50,706,412,000 people have purchased insurance.

The number of insurance purchasers still falls short of the number predicted by the model.



**Figure 5: Expectation Value of  $P_{num}$  in Hurricane Event**

If these two countries had used this modeled budget for premium coverage prior to these two disasters, the insurance companies would have lost money and may not have had the funds to settle the claims. Therefore, the areas where the probability of extreme weather increases, there is a high probability that catastrophe insurance with a low profitability will lose money, but it is still necessary for insurance companies to continue to promote this business as a good way for people to transfer their risks, and at the same time to ensure that the company's profitability is guaranteed by combining insurance programs with a high profitability, as an expression of the correct assumption of social responsibility and the rational organization of funds.

## 7 Model III: Regional Risk Assessment

### 7.1 Fuzzy Comprehensive Evaluation

Considering the **Objective III** mentioned above, our paper established a regional risk assessment model used to estimate the value at risk (VaR) of constructing and developing at the desired location. In order to achieve this objective, we apply a one-object, multi-factor first-level fuzzy comprehensive evaluation (FCE) method to evaluated whether the desired region is suitable to be constructed and developed. **Firstly**, we need to determine the factor set, comment set and weight set, where the factor set is constituted by all relevant factors, the comment set is constituted by various different evaluation indicators or standards, the weight set is the weight allocation among various factors. **Secondly**, we utilized the three sets, established a fuzzy comprehensive judgement matrix. **Finally**, we use comprehensive judgement to obtain the risk comment of this region.

#### 7.1.1 Evaluation Sets Determination

The VaR of a region needs to be comprehensively evaluated from multiple factors, such as the probability of extreme weather, population density. All these factors constituted a factor set, in this model, we selected probability of extreme weather occurrence ( $P_{ewo}$ ), infrastructure quality ( $IQ$ ) and population density ( $PD$ ) as our factors, our factor set is defined as below:

$$U = [u_{P_{ewo}}, u_{IQ}, u_{PD}]$$

Because the evaluation value of each factor is different, in our model, a evaluation standard is defined as our comment set which is shown below:

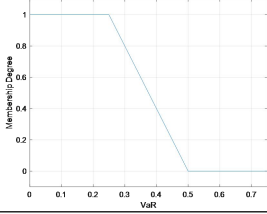
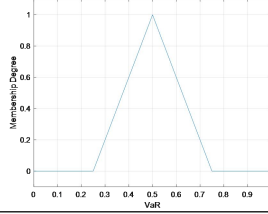
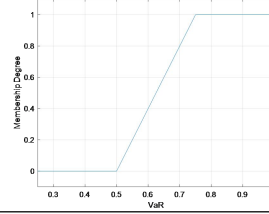
$$V = [Low\ Risk, Medium\ Risk, High\ Risk]$$

Because the impact by each factor in the comprehensive evaluation is different, and the comprehensive evaluation results are not only related to the evaluation of each comment, but also largely depend on the the impact of each factor in the comprehensive evaluation. Therefore we have defined a weight distribution between the factors. The weight set is also regarded as a fuzzy vector shown below:

$$W = [W_{P_{ewo}}, W_{IQ}, W_{PD}], \sum_{i=1}^3 W_i = 1$$

### 7.1.2 Fuzzy Comprehensive Judgement Matrix Determination

Firstly, normalizing and standardizing the local data of  $P_{ewo}$ ,  $IQ$ ,  $PD$  from the equation (1) to obtain three VaRs. Secondly, we defined three membership functions shown below as Table 2. Utilizing these three functions, we can obtain three membership degree for each VaR. The Table 2 was shown below:

Low Risk	Medium Risk	High Risk
		
$\begin{cases} 1, & VaR \in [0, 0.25) \\ \frac{0.5 - VaR}{0.25}, & VaR \in [0.25, 0.5) \\ 0, & VaR \in [0.5, 1.00] \end{cases}$	$\begin{cases} \frac{VaR - 0.25}{0.25}, & VaR \in [0.25, 0.5) \\ \frac{0.75 - VaR}{0.25}, & VaR \in [0.5, 0.75] \\ 0, & Otherwise \end{cases}$	$\begin{cases} 0, & VaR \in [0, 0.5) \\ \frac{VaR - 0.5}{0.25}, & VaR \in [0.5, 0.75) \\ 1, & VaR \in [0.75, 1.00] \end{cases}$

**Table 2: Definition of Three Type of Membership Functions**

For indicator  $u_{Pewo}$ , the membership degree of each comment is a fuzzy subset on  $V$ , the judgement from VaR is defined as:

$$R_i = [VaR_{Pewo1}, VaR_{Pewo2}, VaR_{Pewo3}]$$

which means: According to the probability of extreme weather occurrence ( $P_{ewo}$ ):

- The membership degree of this place being defined as a low risk region is  $VaR_{Pewo1}$
- The membership degree of this place being defined as a medium risk region is  $VaR_{Pewo2}$
- The membership degree of this place being defined as a high risk region is  $VaR_{Pewo3}$ .

So for the three factors, we have the whole fuzzy comprehensive judgement matrix can be defined as:

$$R = \begin{bmatrix} VaR_{Pewo1} & VaR_{Pewo2} & VaR_{Pewo3} \\ VaR_{IQ1} & VaR_{IQ2} & VaR_{IQ3} \\ VaR_{PD1} & VaR_{PD2} & VaR_{PD3} \end{bmatrix}$$

which is a fuzzy relational matrix from  $U$  to  $V$ .

### 7.1.3 Comprehensive Judgement

Utilizing the fuzzy relational matrix  $R$ , we can obtain a comprehensive judgement result:

$$B_{1 \times 3} = W_{1 \times 3} \times R_{3 \times 3}$$

hence we obtained the fuzzy matrix  $B = [b_{low\ risk}, b_{medium\ risk}, b_{high\ risk}]$ , where:

- $b_{low\ risk}$  represents the membership degree of low risk.
- $b_{medium\ risk}$  represents the membership degree of medium risk.
- $b_{high\ risk}$  represents the membership degree of high risk.



Finally we can compare  $b_{low\ risk}$ ,  $b_{medium\ risk}$  and  $b_{high\ risk}$ , the term with largest membership value corresponds to the risk comment of this region.

## 7.2 Model Application

To verify the accuracy of our model, we applied this model in 9 cities in Fujian Province, China, and finally obtained the risk of constructing and developing at these 9 cities.

### 7.2.1 FCE Method Application

Firstly, we established the three factor sets:

$$\begin{aligned} U &= [u_{Pew}, u_{IQ}, u_{PD}] \\ V &= [Low\ Risk, Medium\ Risk, High\ Risk] \\ W &= [0.4, 0.3, 0.3] \end{aligned}$$

Secondly, the relevant data was founded and data pre-processing was done, then we constructed 9 different fuzzy comprehensive judgement matrices for 9 cities:

$$R = \begin{bmatrix} VaR_{Pew01} & VaR_{Pew02} & VaR_{Pew03} \\ VaR_{IQ1} & VaR_{IQ2} & VaR_{IQ3} \\ VaR_{PD1} & VaR_{PD2} & VaR_{PD3} \end{bmatrix}$$

Finally, we obtained 9 fuzzy matrices  $B$ , and define the risk comment of these cities.

### 7.2.2 Result Representing and Analyzing

By model application above, we can obtain the following result:

City	Membership			Final Judge
	Low Risk	Medium Risk	High Risk	
Fuzhou	0.7000	0.0742	0.2258	Low Risk
Xiamen	0.7000	0	0.3000	Low Risk
Quanzhou	0.6839	0.1167	0.1994	Low Risk
Zhangzhou	0.7000	0	0.0862	Low Risk
Putian	0.7000	0.0666	0.2334	Low Risk
Longyan	0.7000	0	0.3000	Low Risk
Sanming	0.5537	0.3601	0.0862	Low Risk
Ningde	0.7000	0.0512	0.2488	Low Risk
Nanping	0.5321	0.1679	0.3000	Low Risk

**Table 3: Data and Final Judge of Nine Cities**

Based on the construction situation of each city, they are all main cities in Fujian, China. They are all relatively well-constructed and well-developed, and the local policy and strategy are relatively completed, so all the nine cities is regarded as low risk region. The result by applying our model is acceptable.

## 8 Model IV: Multi-Criteria Community Development Strategy

### 8.1 Multi-attribute decision analysis model

In response to the problem at hand, we have established a strategy-making model known as the “Multi-Criteria Community Development Strategy”. The objective of this model is to provide superior strategy-making recommendations for community development from the perspective of historical and cultural architecture.

Firstly, our process involves the acquisition of strategy-making information. This can be achieved through the “Regional Risk Assessment Model” above. By utilizing this model, we could obtain the weight sets  $W$  and membership values of influencing factors  $R$ . These weights and values form the foundation of strategy-making process, it is crucial to conduct an in-depth analysis.

Following this, we can assemble the strategy-making information. This step encompasses the ranking and selection of all potential schemes. We calculate the total score of each scheme based on its attribute weights and attribute values. The scheme with the highest score is the one we ultimately require.

Finally, we will propose our recommendations based on this scheme. These recommendations take into account various factors, including the protection of historical and cultural architecture, the development needs of the community, and potential risks.

With this model, we can better understand and manage the risks associated with community development. We can predict potential problems and prepare in advance. At the same time, we can also adjust our decisions based on the results of the model to achieve the best outcomes. In summary, this model provides us with a powerful tool that can assist us in making better decisions for community development.

### 8.2 Determination of Protective Measures

In the Regional Risk Assessment model, we have already analyzed the quality of infrastructure, the probability of extreme weather occurrences, and the impact of population density on risk assessment results based on data. The weight proportions of these factors are determined according to their impact on the risk assessment results. By comparing the three weight, the largest term was be defined as the most unfavorable factor to develop community development. Therefore, we can modify some strategy in order to decrease the influence of the factor.

The advantage of this method is that it allows us to adjust the risk assessment model according to the actual situation, making it more in line with reality. In this way, we can prevent and respond to potential risks more effectively, thereby protecting our communities and infrastructure.

### 8.3 Model Application:

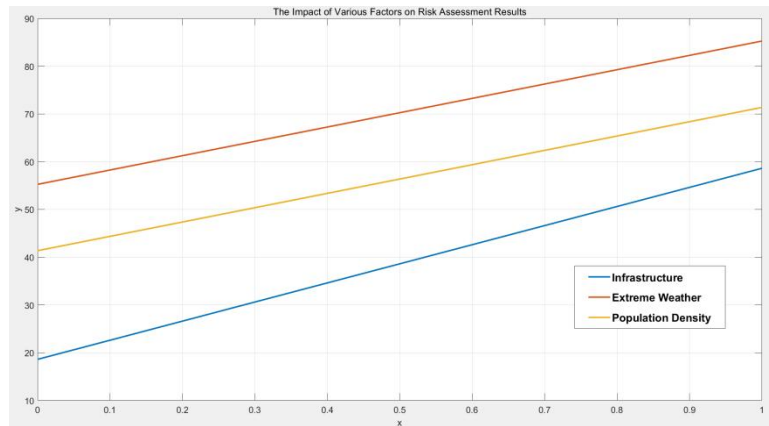
#### The Northern Song Dynasty Imperial Mausoleum in Gongyi, Henan, China

The Northern Song Dynasty Imperial Mausoleum, located in Gongyi City, Henan Province, China, is a cultural heritage site with a rich history. However, according to the above model, the risk assessment result for this location is 57.619478707190744, indicating that it is a Middle-risk area.

The model reveals that among all the factors considered, the quality of infrastructure has the greatest impact on the risk assessment result. This implies that if we could improve the quality of infrastructure, we could significantly reduce the risk level of this location.

To illustrate this point more concretely, we can introduce some formulas. In our model, the risk assessment result is calculated as the weighted sum of multiple factors, namely:

$$R = W_{IQ} \times IQ + W_{ewo} \times P_{ewo} + W_{PD} \times PD \quad (13)$$



Given that the weight of infrastructure quality  $W_{IQ}$  is the largest, when we improve the quality of infrastructure, then the risk assessment result will decrease significantly.

Therefore, our recommendation is to improve the quality of infrastructure. For example: repairing damaged roads, enhancing the structural stability of buildings, or improving the efficiency of public service facilities.

According to the basic situation and disaster situation of Henan cultural relics industry, museums and cultural relics management institutions from 2002 to 2022<sup>[5]</sup>, combined with the detailed expenditure table of the Palace Museum in Beijing<sup>[6]</sup>, it is concluded that:

The Northern Song Dynasty Imperial Mausoleum has a total of 3.64 million yuan for disaster extra renovation costs; and we calculated a premium of 2.91134 million through the model.

According to the total cost of improving infrastructure from 2020 to 2023 given by Yellowstone National Park on the official website<sup>[7]</sup>, the total cost of improving infrastructure required by The Northern Song Dynasty Imperial Mausoleum can be calculated by the proportion of the area, which is 64,301,081.1524 yuan.

## 9 Model Evaluation

### 9.1 Strengths

- **Strengths 1: Extreme Weather System Determination using historical data and advanced mathematical methods.**

**Explanation:** It uses a combination of entropy weight method (EWM), analytic hierarchy process (AHP), and Monte-Carlo simulation to determine the probability of extreme weather occurrence. It also uses a fitting algorithm to predict future trends. This combination of methods allows for a comprehensive and accurate analysis of extreme weather events.

- **Strengths 2: Recognize catastrophe insurance as a public good and control the profitability of insurance companies.**

**Explanation:** The cost of risk avoidance, i.e. premiums, should be added to the calculation of production costs, not ignoring risks just because the probability of an event is low, but preparing for the worst, and combining this with the low profitability of the insurance company to minimize the costs as much as possible and to make people more receptive to this way of avoiding risks.

- **Strengths 3: Models are adaptable in most of situations.**

**Explanation:** The model is a user's estimation of local data using the most accurate data for each region, which is more accurate and applicable than the judgment of using judgmental indicators.

### 9.2 Weaknesses and possible Improvements

- **Weakness 1: Extreme Weather System Determination relies heavily on historical data**

**Explanation:** Due to the unpredictable nature of extreme weather, the probability of extreme weather occurrence may not always accurately predict future events. Additionally, the model assumes that the probability of each type of extreme weather event is independent, which may not always be the case.

- **Weakness 2: Models may not take into account all the factors that can affect community development.**

**Explanation:** The factors may not be fully considered, such as the socioeconomic situation of the community, the policy environment, etc.

## 10 Conclusion

In response to property losses caused by extreme weather, insurance companies have responded to market demand by launching insurance products. After years of practice, people have seen the prospects of this insurance product and found ways to speed up reconstruction and reduce economic losses after catastrophes, giving great impetus to the insurance industry. In the face of natural disasters arising from extreme weather, neither individuals, local governments nor countries can easily withstand such devastating blows. As the world continues to develop, the economy continues to progress, and people accumulate more and more wealth, the impact of unforeseen events is becoming more and more significant. As an example: In the past, when a building was being constructed, it took one year to build one floor. With technological advances, in the same year we have built twenty-story skyscrapers. After the same devastating flood, what used to be a loss of just one floor is now a loss of a twenty-story skyscraper. With the continuous development of economic globalization, the financial markets are globally interconnected, the butterfly effect spreads faster, and a catastrophe affects not only the local economy, but even the global economy. Such characteristics necessitate that we must recover from catastrophes as quickly as possible. This requires insurance companies to help bear the risk and provide the capital to help the economy recover.

However, the money of insurance companies is accumulated through the premiums usually paid by property owners, and the premiums should be treated as a kind of cost by property owners, together with the low profit rate of insurance companies mentioned in our hypothesis, to establish a social system of transferring risks, so as to provide capital for people to rebuild in the face of serious consequences caused by catastrophes, and to contribute to the development of the world's economy. We believe that this is the social responsibility that insurance companies, as companies with a large scale in the financial industry, should assume, as well as the special significance and value of the existence of the insurance industry.

Of course, low profit margins will also give insurance companies a great deal of financial pressure, which requires the industry to carry out reasonable business allocation. For example, when insurance giants are fulfilling this social responsibility instead, other small enterprises that are temporarily incapable of underwriting insurance policies should additionally share the market for insurance products with high profit margins with these giant companies, so that these giant companies can achieve a high profit margin item and a low profit margin item in terms of business allocation. Rationalize the arrangement to promote the continuous development of the company.

People's increased awareness of risk, the deepening globalization of the world economy and other factors continue to drive the insurance industry forward, reflecting the vigorous vitality and great potential of the insurance industry. Therefore, insurance practitioners need to shoulder the responsibility given to the insurance industry by the society while expanding the market, and face the future opportunities and challenges together with the whole man-kind.



## Dear Community Members:

The Song Dynasty, one of the most economically and culturally prosperous dynasties in China's feudal history, and the Royal Tombs of the Northern Song Dynasty are constructed in our community. It shows us that magnificent period of culture, and the stories of those wise rulers and ministers have been passed down through the ages. However, with climate change and an increase in the occurrence of extreme weather events, the preservation of our heritage is being severely tested. In order to showcase our unique funerary culture to the world, we need to spare no effort in preserving the Northern Song Tombs and take immediate action.

We have gone through modeling estimates and we plan:

First, improve the infrastructure of our community, especially the construction of the water supply and drainage system is crucial. Next, improve the infrastructure of the surrounding roads as well as limit the number of tourist visits. After budgeting, we expect to spend about 300,000 CNY per year on insurance and focus on implementing infrastructure improvements. We expect to spend 20 years on a huge project with a total investment of about 65 million CNY, which combined with insurance premiums and other costs will be about 70 million CNY. This is a great plan, although it will require decades of our time and effort and a considerable amount of capital investment, which will require everyone's support and joint efforts. Lastly, through the exploration of cultural, educational and tourism potentials, innovative and novel ways of touring the landmark will increase its popularity.

We eagerly anticipate working together to achieve this significant goal – enhancing the visibility of this important landmark building, acting as a catalyst for economic development in our community, and yielding returns and impacts that far exceed the investment.

Sincerely,

ICM TEAM #2422426



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# AI Report

## 1. OpenAI: ChatGPT(Feb. 2,2024 version, ChatGPT-3.5)

**Query 1:< The impact of climate change on insurance liability determination>**

**Output:**

Climate change has a wide-ranging impact on the liability assessment within the insurance industry, primarily manifested in the following aspects:

**Risk Assessment and Pricing:** Climate change may lead to an increase in extreme weather events such as storms, floods, and droughts. The risks associated with these events may affect insurance companies' risk assessment and pricing strategies. Insurers need to more accurately assess climate-related risks and adjust premiums accordingly.

**Coverage Scope of Policies:** With the frequency and intensity of disasters increasing due to climate change, insurance companies may need to reassess the coverage scope of various policies. Some regions may become high-risk areas, while places traditionally considered low-risk may become more prone to risks.

**Reinsurance Market:** Climate-related risks result in changes in the reinsurance market. Reinsurance companies may need to more specifically bear climate risks, potentially leading to an increase in reinsurance costs, thereby impacting insurance companies' overall costs.

**Product Innovation:** Faced with new risks arising from climate change, insurance companies may need to innovate products to meet customer demands. For example, introducing specific insurance products tailored to climate change risks, such as climate adaptation insurance.

**Legal Liability:** Climate change may give rise to more legal liability issues. Insurance companies may need to reassess their legal responsibilities towards policyholders in the event of disasters and manage legal affairs accordingly based on the impacts of climate change.

**Long-Term Sustainability Considerations:** Long-term climate change trends may require insurance companies to consider sustainability factors over an extended period. This includes sustainable risk management strategies, asset allocation, and the sustainability of business models.

**Regulatory Requirements:** As awareness of climate change increases, regulatory bodies may strengthen their requirements for insurance companies in terms of climate change risk management and transparency.

Overall, the impact of climate change on liability assessment in the insurance industry is complex and comprehensive, necessitating adjustments by insurance companies in risk management, product design, and strategic planning. Additionally, collaboration with other stakeholders such as government and research institutions may be necessary to collectively



address the challenges posed by climate change.

## 2. OpenAI: ChatGPT(Feb. 2,2024 version, ChatGPT-3.5)

**Query:< Assuming the insurance unit price is B, the compensation amount is C, and the number of insured persons is A. Seeking the relationship between the three >**

### **Output:**

The relationship between insurance premium per unit (B), claims amount (C), and the number of insured individuals (A) can be expressed through the following formulas:

Total Premium = Insurance Premium per Unit  $\times$  Number of Insured Individuals  
Claims Ratio = Claims Amount / Total Premium.

Here, the total premium represents the sum of all premiums received by the insurance company from the insured individuals. The claims ratio indicates the proportion of claims amount to the total premium.

The specific relationship can be derived through the following steps: Total Premium = Insurance Premium per Unit  $\times$  Number of Insured Individuals (Total Premium is directly proportional to both insurance premium per unit and the number of insured individuals). Claims Ratio = Claims Amount / Total Premium (The claims ratio is inversely proportional to the total premium and directly- proportional to the claims amount). In practical applications, insurance companies typically determine the insurance premium per unit based on historical data, risk assessments, and other factors. Adjustments within a certain range may be made to ensure the sustainability of insurance operations.

## 3. OpenAI: ChatGPT(Feb. 3,2024 version, ChatGPT3.5)

**Query: < Probability of occurrence of global extreme weather>**

### **Output:**

The probability of global extreme weather occurrences is a complex and dynamic issue influenced by various factors, including climate patterns, geographical location, atmospheric conditions, and more. Extreme weather encompasses events such as extreme heat, heavy rainfall, hurricanes, tornadoes, and others.

Climate change is a significant factor contributing to the increased frequency of extreme weather events. Human activities leading to greenhouse gas emissions have resulted in global temperature rise, potentially altering climate patterns and increasing the likelihood of extreme weather events. Scientific studies indicate that as global temperatures increase, the frequency and intensity of extreme weather events may also rise.

However, accurately assessing the probability of global extreme weather is challenging due to the complexity of weather systems and the multitude of influencing factors. Scientists utilize climate models and meteorological data for predictions, but uncertainties still exist.

Additionally, the probability of meteorological events may vary based on geographical location, with certain regions being more susceptible to specific types of extreme weather.

In general, there has been a demonstrated increasing trend in the probability of global extreme weather occurrences in recent years. However, the specific probability depends on the particular time and location. Scientists and meteorologists continually enhance our understanding and prediction of extreme weather events through ongoing research and observations.

#### **4. OpenAI: ChatGPT(Feb. 5, 2024 version, ChatGPT-3.5)**

**Query: < Is the relationship between insurance value and insured value linear or nonlinear>**

**Output:**

In practical scenarios, the relationship between insurance premiums and insured values is often non-linear. This is because insurance companies take into account multiple factors in their pricing, and the relationships among these factors may not be simple or linear.

The reasons for non-linear relationships include:

**Non-uniform Risk:** Different insured entities may have significantly different risk levels. In certain cases, insurance companies may charge higher premiums for high-risk insured entities and lower premiums for low-risk ones, resulting in a non-linear relationship.

**Rate Adjustments:** Insurance companies adjust rates based on empirical data, risk assessments, and market changes. These adjustments are typically non-linear and are carried out using complex models and algorithms.

**Additional Fees and Adjustment Factors:** Insurance companies may introduce additional fees, adjustment factors, or other elements that are often non-linear and may vary with changes in insured values.

**Market Competition:** Competition and market demand in the insurance industry can also lead to non-linear relationships. Insurance companies may adjust their premium levels based on market demand and competitive conditions, resulting in non-linear relationships.

Despite this, some simplified models or specific types of insurance may use approximate linear relationships to estimate the connection between insurance premiums and insured values. In practical applications, accurate premium calculations often require consideration of more factors, utilizing more complex mathematical models and algorithms.

#### **5. OpenAI: ChatGPT (Feb 5, 2024 version, Github Copilot)**

**Query: <If the probability of extreme weather occurrence, infrastructure quality, and population density are weighted and combined into a risk index from 0 to 100, and**

**now through weight analysis, it is found that which element has the greatest impact on the risk index, what can this be called a mathematical model?>**

**Output:**

This mathematical model can be called a weighted scoring model or multi-attribute decision analysis model. In this model, each factor (such as the probability of extreme weather occurrence, infrastructure quality, population density) is assigned a weight, which reflects the impact of the factor on the overall risk index. Then, these weighted factors are combined to form an overall risk index. By comparing the weights of each factor, we can determine which factor has the greatest impact on the risk index. This model is widely used in risk assessment, decision analysis, and priority ranking.

## **6. OpenAI: ChatGPT (Feb 5, 2024, version, Github Copilot)**

**Query: <Method of obtaining the weight ratio>**

**Output:**

There are many methods to determine the proportion of weights, and the specific choice depends on the characteristics of your data and research objectives. Here are some common weight determination methods:

**Analytic Hierarchy Process (AHP):** This is a qualitative and quantitative research method for calculating weights. It uses pairwise comparison to establish a matrix, using the relativity of the size of numbers, where the larger the number, the more important it is, and the higher the weight. The final calculation determines the importance of each factor.

**Ordinal Graph Method:** The ordinal graph method also uses the relativity of the size of numbers. The data is analyzed by experts for each indicator.

**Entropy Method:** The entropy method is an objective assignment method. It uses the amount of information carried by the data to calculate the weight, resulting in relatively objective indicator weights.

**CRITIC Weight Method:** The CRITIC weight method is an objective assignment method. Its idea is to use two indicators, namely contrast intensity and conflict indicators. Contrast intensity is represented by standard deviation. If the data standard deviation is larger, it means that the fluctuation is larger, and the weight will be higher; conflict is represented by correlation coefficient. If the correlation coefficient value between the indicators is larger, it means that the conflict is smaller, and its weight will also be lower.

**Factor Analysis and Principal Component Method:** These two methods use the principle of data information concentration, and use variance explanation rate to calculate weights.

Each of these methods has its own applicable scenarios and advantages and disadvantages. You can choose the most suitable method based on your specific needs and data characteristics. I hope this answer is helpful to you!

**7. OpenAI: ChatGPT(Feb. 5, 2024 version, ChatGPT-3.5)**

**Query: < We are very much looking forward to working together to realize this great goal. To give this important landmark building greater visibility, to be a driver of economic development in our community, and to bring us a return and impact that far outweighs the investment. Check if there are any grammar errors in this paragraph, and if so, please indicate them>**

**Output:**

There are no obvious grammar errors in this paragraph, but it can be slightly improved to improve fluency. The following are modification suggestions:

“We are eagerly anticipating working together to achieve this significant goal – to enhance the visibility of this important landmark building, act as a catalyst for economic development in our community, and yield returns and impacts that far exceed the investment.”

This modification makes the sentences smoother and more in line with the formal writing style. I hope it will be helpful to you!