Underwrite or Not: in a World of Natural Disasters

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Abstract: Extreme-weather events are now a growing concern for many regions and communities around the world. The sustainability of property insurance under such context has already becoming a huge problem. However, for lots of communities, their historical sites and spiritual architectual icons are particularly vulnerable under rampant natural disasters, and the huge losses make it impossible for insurance companies to protect them properly and instantly. It is time we step in to stop them choking from bad weathers, from a province to an ancient arch bridge.To address such issue, aquantitative model is established: Underwriting Risk Assessment Model, based on AHP.This model is designed for insurance companies to decide whether to underwrite in the regions where extreme-weather events are on the rise. To realize it, I harnessed level-one analytic hierarchy process (AHP) not only to rate the risk degree for certain regions, but also set the framework of assessment model. Through establishing judgement matrices, I obtained and compared the ratings and weights for the Western USA and the Southeast China to demonstrate the model, and to drew a conclusion.Finally, sensitivity analysis proved the objectivity, reasonableness and robustness of the model. With such certificate in hand, I am more than ready to help communities with their urgent need to make rational and favorable decisions.

Keywords: Property Insurance; underwrite; Extreme-weather Events; AHP; Assessment Model

1. Introduction

1.1 Problem Background

Climate change is influencing weather-related natural disasters. The current scientific consensus is that human greenhouse gas emissions since the industrial revolution are overwhelmingly responsible for rising temperatures in the atmosphere and oceans, as is shown in figure 1. The consequences of global warming are varied, ranging from frequent extreme-weather events to meteorological disasters. And the upward trend of both also corresponds to each other.

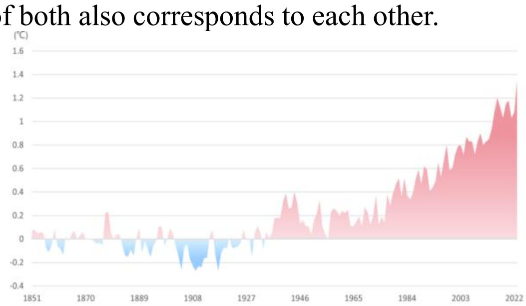

Figure 1. Global Temperature Compared to the 1850-1900 Average

Extreme-weather events are becoming a huge crisis for property owners and insurers. Conditions are expected to get worse as losses from severe weather-related events are likely to increase. At the same time, the proportion of insured losses in total losses is also increasing, as what the figure 2 shows. In regions where extreme weather events are on the rise, adding to more burdens of compensation payouts, insurance companies are facing complex underwriting decisions.

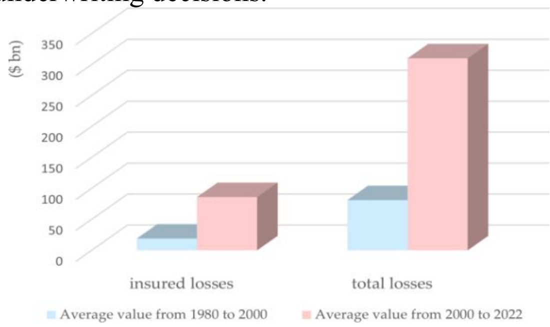

Figure 2. Global Total Losses and Insured Losses from Major Natural Disasters during 1980-2000 and 2000-2022

1.2 Literature Review

First, LiaoBaiyu, and WenJiale summarized the common research methods and models for natural disaster risk assessment and cross-disciplinary applications by organizing a large amount of literature on natural disaster risk assessment[4] .

Second, Hu Xianzhen, Fu Shaojie, and Chi Hongqing conducted an informa- tive coupled model for geohazard risk assessment based on hierarchical analysis, which provided a risk assessment method with reference significance[3] .

Third, He Xiaowei, Tong Jinlin, Liu Yixin et al. analyzed the status quo, dilemma and optimization of property insurance system under extreme weather by taking China's flood disaster insurance as an example[2] .

Fourth, Ma Hengsheng, Gao Jiaxing, and Zhao Qian constructed a residential project site selection model based on the multi-indicator decision-making method of indicator equilibrium expectation, which is meaningful for the improvement of decision-making accuracy and rationality of real estate developers[5] .

2. Assumptions and Explanations

Assumption 1: The model assumes that the profit model of insurance companies is solely based on dead margin return. There are three main sources of revenue, interest margin, dead margin, and expense margin. Among them, the occurrence of extreme weather events is directlyrelated to the dead margin return, i.e., an significant increase in the probability of payouts leads to substantial losses for insurance company. The two other revenue sources are therefore ignored.

Assumption 2: The model assumes that, certain small-scale climate disasters with limited impact for human beings as a whole, are not considered. Climate disaster types are diverse and have complex origins, making it impractical to use algorithms that includes all types of disasters.For computational convenience and to ensure the universality of my model, only typical extreme-weather events and disasters are considered, i.e., 1) droughts and wildfires, 2) tropical storms, 3) rainstorms and floods, 4) thunderstorms, 5) winter storms and blizzards.

Assumption 3: The model assumes that the risk of extreme-weather events for a region has internal homogeneity. In general, a region contains smaller administrative regions, e.g.the relationship between provinces and cities in China. Due to the high similarity of extreme-weather events in the same geographical area, the model ignores the differences between them. Thus, under a certain extreme-weather event, the judgment matrix of a smaller region is the same as that of other smaller regions in the region.

3. Notations

Some important mathematical notations in this paper are listed in the figure 3.

Symbol	Description	Unit
x	Number of people	
r	Risk coefficient	/
c	Compensation amount	$
a	Compensation amount/ Risk coefficient	$
r_A	America risk coefficient	/
r_C	China risk coefficient	/
P	The rate of participating insurance	/
I	Insured amount	$
P_0	Net profit	$

Figure 3. Mathematical Notations

4. Underwriting Risk Assessment Model

4.1Weight Solution for Extreme-weather Events

The model's construction methodology is Analytic Hierarchy Process (AHP). It involves establishing a hierarchical structure to transform human-brain judgments into comparisons of importance between various factors, facilitating the conversion of qualitative judgments that are difficult to quantify into an algorithm based on comparable importance. Thus, in order to judge the risk for insurance companies in a more scientific way, I compared the importance of 5 major extreme-weather events I chose, and apply them in the analysis of 2 chosen areas - southeast China and western America, as is shown in figure 4.

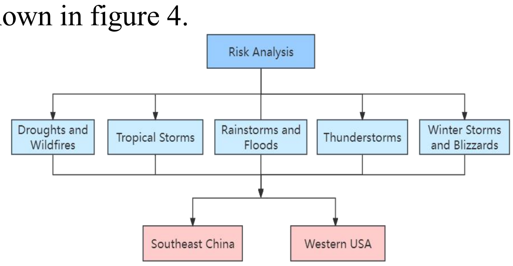

Figure4.AHPStructureofRiskAnalysis

First, I collected the data of the annual cost and compensation from insurance companies of each event worldwide, 2023, in Table 1.

According to the data, I set the scales of the judgement in Table 2. I correlate reasonably the scales with the differences between losses caused by different extreme-weather events for every $ 1 billion, and define meanings for the scales.

Table 1. Annual Cost and Compensation of Chosen Extreme-Weather Events in 2023

Unit: $ bn	Loss	Compensation
droughts and wildfires	69	39
tropical storms	100	60
rainstorms and floods	54.3	13
thunderstorms	32	14.44
winter storms and blizzards	30.1	15

Table 2. Parallel Table for Scale and Meaning

Scale	Meaning	Range
1	equally devastating	<10
3	slightly devastating	10-30
5	obviously devastating	30-50
7	intensely devastating	70-90
9	extremely devastating	90-110

Next, I obtain the judgment matrix between each two extreme-weather events.

Next, I test the consistency of this judgment matrix. The result of calculation for consistency index (CI) is:

$$CI = \frac{\lambda_{max}-n}{n-1} = 0.0087 \quad (1)$$

Table 3. Judgement Matrix

	dw	ts	rf	th	wb
dw	1	1/3	2	4	4
ts	3	1	5	7	7
rf	1/2	1/5	1	2	2
th	1/4	1/7	1/2	1	1
wb	1/4	1/7	1/2	1	1

Note: abbreviation notice: dw = droughts and wildfires; ts = tropical storms; rf = rainstorms and floods; th = thunderstorms; wb = winter storms and blizzards.

Table 4. Average Random Consistency Index (ARI)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59

According to the random index (RI) acquired from Table 4, I can calculate the result of consistency ratio (CR) as follows:

$$CR = CI / RI = 0.0078 \quad (2)$$

CR<0.1, so I clearly pass the consistency test. Setting ωi as the the weight of the i-th element of A, setting n as the number of criterion layer, here n = 5. Assume that the matrix A is:

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} = \begin{pmatrix} 1 & 1/3 & 2 & 4 & 4 \\ 3 & 1 & 5 & 7 & 7 \\ 1/2 & 1/5 & 1 & 2 & 2 \\ 1/4 & 1/7 & 1/2 & 1 & 1 \\ 1/4 & 1/7 & 1/2 & 1 & 1 \end{pmatrix}$$

The weight vector I obtained through arithmetic average method is:

$$\omega_i = \frac{1}{n}\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} (i,j,k = 1,2,3,4,5) \quad (3)$$

Additionally, in order to ensure the accuracy, I also use geometric average method and eigenvalue method to obtain the weights, and calculate the average value of them thereafter. The final weight table I obtain is as follows, marking the result of weight solution in this stage, as is shown in table 5.

Table 5. The Weight Table of Extreme-Weather Events

extreme-weather events	weight
droughts and wildfires	0.227
tropical storms	0.5293
rainstorms and floods	0.1173
thunderstorms	0.0632
winter storms and blizzards	0.0632
total points	

4.2 Operation and Demonstration of Model

After data investigation, I selected two regions with large differences in extreme-weather events on two different continents:1) the western United States, including States of WA, OR, CA, NV, UT, and AZ. 2) the southeast China, including Provinces of Zhejiang, Jiangxi, Fujian, and Guangdong. Thus, the data collection of the model is based on the two regions.

Therefore, It's able to derive a judgment matrix for each extreme-weather event in the two regions, as is shown in table 6. These five matrices are consistent matrices, so they clearly pass the consistency test.

Finally, I find the respective scores and weights of the two regions I chose through the arithmetic average method, and get the results of AHP analysis thereafter, as the table 7 presents.

Table 6. 5 Judgement Matrices for the Two Regions

droughts and wildfires	Western USA	Southeast China
Western USA	1	3
Southeast China	1/3	1
tropical storms	Western USA	Southeast China
Western USA	1	1/4
Southeast China	4	1
rainstorms and floods	Western USA	Southeast China
Western USA	1	1/7
Southeast China	7	1
thunderstorms	Western USA	Southeast China
Western USA	1	1/2
Southeast China	2	1
winter storms and blizzards	Western USA	Southeast China
Western USA	1	1
Southeast China	1	1

In the last step of the calculation I use the following formula to help decide where to underwrite for insurance companies:

$$x \cdot P \cdot I - c = 0 \quad (4)$$

Table 7. AHP Final Results of the Model

extreme-weather events	weight	Western USA	Southeast China
droughts and wildfires	0.227	0.75	0.25
tropical storms	0.5293	0.2	0.8
rainstorms and floods	0.1173	0.125	0.875
thunderstorms	0.0632	0.333	0.667
winter storms and blizzards	0.0632	0.5	0.5
total points		0.3434181	0.6565819

The standard is that, if P0 > 0, underwrite; if P0 is higher in a region, insurance company should prioritize underwriting that region. Bring in data. It is reasonable to assume data, I=50, P=80% . Therefore, according to the table 8, insurance companies should underwrite in Southeast China.

Table 8. Final Calculation Results of Compensation and Profit (unit $bn)

Extreme-weather Events	Weights	Western USA	Southeast China
droughts and wildfires	0.227	0.75	0.25
tropical storms	0.5293	0.2	0.8
rainstorms and floods	0.1173	0.125	0.875
thunderstorms	0.0632	0.333	0.667
winter storms and blizzards	0.0632	0.5	0.5
Total Scores		0.3434181	0.6565819
Compensation Amount		27	51.6255
Net Profit		4.435	152.3745

Meanwhile, according to the Model I, regarding the influence of property owners' behavior in areas experiencing extreme-weather events, if the policyholder is in an uninsured area, he can negotiate with the insurance company to increase the amount of insurance coverage, so that the insurance company is willing to insure there. If a large number of owners choose to relocate due to extreme weather impacts, insurance companies may choose not to operate in the area due to low revenue and profits brought by the insufficient population base.

5. Model Sensitivity Test

For information, the scale when filling in the judgement matrices in the model is based on table 3.To determine whether the model is affected by the preset scales, I changed the scale moderately and found that the change was not significant and error was within the tolerable range, as shown in figure 5. It can be seen that the model is stable, which is capable and competent enough to solve practical problems.

6. Model Evaluation

6.1Strengths of the Model

Strength 1: the model is close to reality. Each criterion are selected and set from official data sources, adding to their credibility. Therefore, the model is good simulations of the reality.

Strength 2: the model is reasonable. The general idea of comparison and evaluation of AHP consists the essence of the model. I make adjustments according to the problems and keep narrowing down the scope of the selected areas, which isreasonable, reliable and transferable. Moreover, I also exclude negligible factors in reality, such as the revenue sources other than the mortality margin for insurance companies, adding to the convenience and operability.

Strength 3: the model is robust. The result of sensitivity test shows that data fluctuations have little impact on the model, indicating that the model is able to effectively resist data fluctuations.

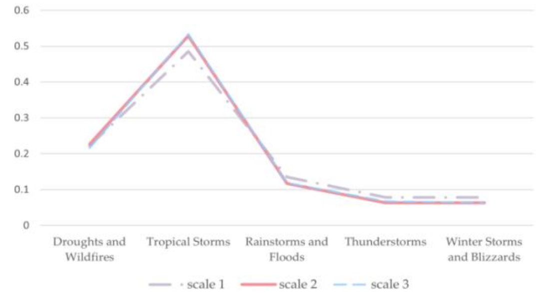

Figure 5. Sensitivity Test Results

6.2 Weaknesses of the Model

Weakness 1: Limitations of the evaluation criteria selected. Although the judgment criteria of the evaluation model are outlined after referring to numerous literature, they may still not be comprehensive enough. In the process of modeling,more evaluation criteria can be added to increase the authenticity and accuracy of the model.

Weakness 2: The unpredictability of occurrence and potential devastation ofextreme-weather events. Extreme weather itself is unknown and sudden. Although the model has tried to analyze major events in different places in detail and able to judge the trend, It's still not combined with feasible extreme-weather prediction models.

7. Conclusion

In a word, this article provided insurance companieswith a risk assessment model for underwriting extreme weather regions quantitatively, selecting the western U.S. and the southeastern region of China, and the model quantified the judgment matrix by weighting to derive the results of the AHP hierarchical analysis of disasters in the two regions, and based on the insurance company’s profit formula, concluded that insurance companies should underwrite insurance in the southeastern region of China compared to the two regions. The creation of this model also reflects the importance of underwriting in the current extreme weather conditions.

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