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Insurance risk assessment system foradaptation to extreme weather

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Abstract: *With the increasing global climate change and the increasing impact of extreme weather on property owners and the insurance industry, the risks of category II groups in extreme weather have attracted more and more attention. This paper constructs a complete insurance risk assessment system from the meteorological, local basic conditions and humanities and art dimensions. The entropy weight method and ahp are used to solve the objective weight and subjective weight respectively, and then the comprehensive weight of each index is solved according to the least square optimization combination algorithm. Taking New York City as an example, this paper uses the constructed evaluation system to score it, and puts forward relevant suggestions for the municipal government according to the scores.*

Keywords: *Toughness assessment; Least Squares Optimisation Weight Model; Analytic Hierarchy Process*

1. Introduction

In recent years, the world has suffered more than 1,000 extreme weather events caused by more than $1 trillion in damage, the global climate is undergoing severe changes, such as floods, hurricanes, tornadoes, droughts and wildfires and other extreme weather has brought great impact on people's living environment, compared with the 30-year average. Insurance claims for natural disasters increased by 115% in 2022. Because of this, weather-related events have driven property insurance premiums up rapidly, and real estate companies and insurance companies are facing unprecedented difficulties[1]. It is worth noting that the insurance industry is facing a double dilemma: the profitability of insurers and the affordability of customers. This will lead to home insurance becoming harder to find and more expensive[2]. If the insurance company is unwilling to undertake the guarantee in most cases, the enterprise will face bankruptcy. However, if the risk required by the property insurance is too high, the enterprise will also slow down the development speed of the enterprise because of high claims[3]. Therefore, how to improve the sustainability of real estate insurance and properly consider the construction and development of real estate, insurance companies urgently need a set of insurance risk assessment model that accepts climate to decide whether to accept the insurance demand of a certain region, so as to meet the needs of consumers and companies in the future development.

In today's era of frequent extreme weather, aggressive weather has become an important factor in the survival of homeowners and insurance companies[4]. According to Munich Re, thunderstorms in the United States caused $32 billion in losses in 2022 alone, two-thirds of which came from the insurance industry, which has a huge impact on the insurance industry. How to help insurance companies make better decisions about whether to accept insurance, taking into account the impact of extreme weather and the preservation of local heritage. Based on this research background, a reasonable mathematical model is established to try to solve this problem.

2. Model assumption and symbol description

2.1 Model assumption

To simplify our problems, we make the following basic assumptions, each of which is adequately justified.

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(1) All data are authentic.

(2) Due to limited data, extreme weather only takes into account the impact of storms, storms, droughts and other weather.

(3) The influence of other factors other than meteorological, economic construction, culture and entertainment on risk assessment is ignored.

(4) Assume that the quality of the insured property is qualified, and exclude the impact of the low quality of the house resulting in the loss of the house in extreme weather resulting in insurance claims.

(5) It is assumed that the selected regions experiencing extreme weather events are common and representative.

(6) The study focuses on insurance claims caused by extreme weather, excluding the impact of ambiguous claims.

2.2 Symbol description

The key symbols used in this article are listed in Table 1.

Table 1: Notations used in this paper

symbol	Symbol specification
CDD	the maximum number of consecutive days during a year with precipitation less than one millimeter
ARP	Average rainfall for the previous year
Rx5Day	the monthly maximum consecutive 5-day precipitation amount in a month
FPP	Forecast precipitation for the next period
T10	the percentage of days in the month in which the low temperature is below the 10th percentile
AT	Average annual temperature of insured ground
T90	the percentage of days in the month in which the high temperature exceeds the 90th percentile
WP90	the percentage of days in the month in which the wind power exceeds the 90th percentile of the reference period.
FW	Forecast winds for the latter period
AW	Annual mean of wind
TCE	Total personal consumption expenditures
TCP	Percentage change in PCE of total consumption expenditure
GDP	Percentage change in GDP compared to previous period
PI	Percentage change in personal income compared with previous period
PIC	Personal income change
FI	The contribution of finance and insurance to changes in personal income
CI	The contribution of construction to changes in personal income
IP	Whether the insured place is in a coastal area or plateau area (yes 1, no 0)
Sea Level	Change of sea level at insured place
ORV	Outdoor recreation adds total value
TOR	Total outdoor recreation
ORE	Outdoor recreation employment
AC/GDP	The art and culture industry accounts for the share of GDP
ACV	National artistic and cultural production added value
MI	The museum industry in the region contributes to GDP
RE	Real estate sector contributes to GDP
AE	Arts education contributes to GDP
IWP	Independent artists, writers and performers contribute to GDP

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3. Data Preprocessing

3.1 Source of data

The weather data in this paper comes from Actuaries Climate Index data, in which the city-related economic data comes from the relevant databases of the US Bureau of Economic Analysis and the US Bureau of Labor Statistics.

3.2 Handling Missing Values

(1) Substitution of state and city indicators

In the relevant data obtained from the US Bureau of Economic Analysis, the US Bureau of Labor Statistics, etc., due to the different forms of data disclosure, there are two types of data that are ultimately obtained: one is the relevant data specific to the city, and the other is the relevant data of the US state. Since the rating system in this paper takes cities as observation samples, in this case: for the j index Cj, if city-specific data cannot be found, in this case, the data of the large state where the city is located will represent the original data of the experimental city.

(2) Absence of time series data

For the collected weather data, there may be missing values, which will destroy the stationarity of the data set and interfere with the forecasting process. Therefore, according to the trend of adjacent data of missing values, this paper adopts linear interpolation method to supplement missing values. For the JTH indicator Cj, intermediate data is missing, such as the percentage of days in the month when the temperature is below the 10th quantile for indicator C4.

3.3 Data integration

After completing the processing of missing data, the positive and negative indicators are uniformly processed into positive indicators. The specific steps are as follows:

(1) For positive indicators:

$$X_{qw} = \frac{k_{qw} - mink_{qw}}{maxk_{qw} - mink_{qw}}$$

(2) For negative indicators:

$$X_{qw} = \frac{maxk_{qw} - k_{qw}}{maxk_{qw} - mink_{qw}}$$

For the formulas in (1) and (2), kqw is the original value of sample q on the index w.

3.4 Deleting Abnormal Data

For the problem of possible outliers in the data set, this paper processed the original data of all indicators by box diagram, and carried out outlier detection. At the same time, in order to prevent the disturbance of outliers to the construction of the index system, the values located in 1% and 99% of the quantiles are eliminated, and the indentation process is adopted.

3.5 Data standardization processing

Due to the different dimensions of the indicators, the dimensions of a single indicator will inevitably differ. For example, the dimension of the total personal consumption expenditure (TPE) is 1,000,000, while the dimension of the contribution of the insurance industry to the local GDP (CFIT) is 1. The gap between the dimensions is huge, which may affect or even ignore the impact of indicators with small dimensions. Therefore, all raw data are standardized in this paper to keep their dimensions consistent.

ISSN 2616-5902 Vol. 6, Issue 6: 213-219, DOI: 10.25236/AJBM.2024.060632

4. Index selection

We crawled data from 19 regions such as Arkansas and Kansas to conduct experiments. Two dimensions of meteorological and local basic conditions are mainly considered. The meteorological dimension includes three secondary indexes of rainfall, temperature and wind power, and a total of eight tertiary indexes. The dimension of local basic situation includes three secondary indicators: geographical location, residents' living standards, and the development of related industries, and a total of nine tertiary indicators.

From the meteorological dimension, this paper mainly regards rainstorm, hurricane, high temperature and drought as the main extreme weather effects. According to Munich Re, the cost of thunderstorms, hail and tornadoes is rising every year, with thunderstorm-related losses in the United States reaching $32 billion in 2022. In industrialized countries, many thunderstorm-related losses are borne by insurance companies, so this paper focuses on the impact of extreme weather on the insurance industry, and initially selects eight indicators that affect extreme weather.

In some areas with frequent extreme weather, there may be some scenic spots and historical sites, which have rich cultural value and need to be protected accordingly. Considering this special situation, this paper adds the dimension of culture and art, which together with meteorology and local economic construction constitute the three dimensions of the index system. Nine three-level indicators, including the contribution of ancient buildings to local GDP and the contribution of museums to local GDP, were added to measure the development of local art industry and scenic spots from the perspective of microeconomics. The specific indicators are selected in Table 2.

Table 2: Primary index of insurance risk assessment

Target variable	First-level indicator	Secondary indicator	Third-level indicator	unit
Risk assessment of insurance in the target area	*Meteorological dimension*	*Rainfall*	C1 CDD	D
			C2 ARP	D
			C3 Rx5Day	mm
		Temperature	C4 T10	%
			C5 AT	Celsius
			C6 T90	-
		Wind force	C7 WP90	D
			C8 AW	-
	Local basic situation dimension	*Living standards of residents*	C9 TCE	Millions of dollars
			C10 TCP	-
			C11 GDP	-
			C12 PI	-
			C13 PIC	Millions of dollars
		Related industry development	C14 FI	-
			C15 CI	-
		Geographical location	C16 IP	-
			C17 Sea level	mm
	Cultural and artistic dimension	*Outdoor entertainment Art industry*	C18 ORV	-
			C19 TOR	Self
			C20 ORE	people
			C21 AC/GDP	%
			C22 ACV	Thousands of dollars
			C23 MI	-
			C24 RE	-
			C25 AE	-
			C26 IWP	-

5. Measurement of weights

5.1 Objective weight

In the objective weighting, the entropy weight method is used to measure the weight. The internal logic of entropy weight method is as follows: according to the discrete degree of each index, the entropy weight of each index is calculated by using information entropy. When the degree of data dispersion is larger, the corresponding information entropy is smaller. That is, the more information contained in the data, the greater the weight corresponding to the indicator. The main steps are:

(1) Calculate the information entropy of the index:

$$E_j = -\frac{1}{lnm}\sum_{i=1}^{m} p_{ij} lnp_{ij} \ ,p_{ij} = \frac{f_{ij}}{\sum_{i=1}^{n} f_{ij}} \tag{1}$$

Were, if p_{ij}=0, $\lim_{p_{ij}\to 0} p_{ij} = 0$,

(2) Calculate the weight of each index by information entropy:

$$W_j = \frac{1-E_j}{\sum_{j=1}^{n}(1-E_j)} \tag{2}$$

5.2 Subjective weights

This paper uses AHP-analytic hierarchy process (ahp) to measure the subjective weight of the index, which is mainly used to solve complex multi-objective decision-making problems. It can decompose a complex multi-objective problem into several simple objectives, and calculate the hierarchical ranking and comprehensive total ranking by fuzzy pricing quantification and qualitative analysis of indicators. The basic steps are as follows:

1) Problem decomposition. The complex goal problem is classified by attributes and the relevant factors are sorted from high to low, forming a multi-level and multi-objective evaluation system.

2) Expert score. In this article, we asked ten experts from Fortune Global 500 financial companies to rate the constructed index system using a nine-step scale.

3) Consistency test of expert judgment matrix:

$$\mathrm{CI} = \frac{\gamma_{\max}-\mathrm{n}}{\mathrm{n}-1}, \mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \tag{3}$$

Where n represents the order of the judgment matrix, γ_max is the largest eigenvalue, and RI represents the average random consistency index. When the value of CI is larger, the consistency of the judgment matrix is worse.

5.3 Comprehensive weights

After obtaining subjective weight and objective weight, this paper combines the two methods to make up for the shortcomings of a single method, and at the same time synthesizes their respective advantages to improve the accuracy of index weight measurement. It is assumed that the entropy weight obtained by the analytic hierarchy process is ωj, the entropy weight obtained by AHP-analytic hierarchy process is φj, the comprehensive weight obtained is αj, and the matrix of the evaluation index system after the normalization of matrix S is T. For all evaluation indicators, the deviation of subjective and objective weights should be as small as possible. Therefore, this paper establishes the least square combined optimization weight model to solve the comprehensive weight of indicators:

$$\mathrm{MinF}(\alpha) = \sum_{i=1}^{m}\sum_{j=1}^{n}\left\{\left[(\varphi_j - \alpha_j)S_{ij}\right]^2 + \left[(\omega_j - \alpha_j)S_{ij}\right]^2\right\} \tag{4}$$

Where, $\sum_{j=1}^{n}\alpha_j = 1$, $\alpha_{ij} \geq 0$ (j=1,2,3,...,n)

The Lagrange method is used to solve the above model, and the final weight of the index is obtained. As shown in Table 3.

As can be seen from the analysis of Table 3, the weight of meteorological dimension is 0.6123, indicating that in this evaluation index, emphasis is placed on the impact of extreme weather and it is regarded as the first-level index with the highest weight of risk assessment index. The weight of culture and art dimension is 0.2778, ranking second. It mainly considers the economic contribution brought by the development of local soft culture and scenic spots, and takes it as the second weight and indicator of the risk assessment index. The weight of the local basic conditions dimension is 0.1099. In this dimension, the paper mainly considers the resilience of the local area to withstand extreme weather. Generally speaking, the better the underlying economic development of a region, the less residents will be affected when it faces extreme weather and major disasters. Therefore, starting from these three dimensions, this paper constructs an insurance risk assessment system adapted to extreme weather changes to help insurance companies better judge whether to accept insurance demand and better price insurance, so as to promote the sustainable development of the insurance industry.

Table 3: Comprehensive weight table

Target	Weight	Target	Weight	Target	Weight
C1	0.203	C10	0.008	C19	0.045
C2	0.012	C11	0.036	C20	0.072
C3	0.064	C12	0.002	C21	0.008
C4	0.149	C13	0.018	C22	0.031
C5	0.104	C14	0.004	C23	0.019
C6	0.040	C15	0.005	C24	0.004
C7	0.025	C16	0.012	C25	0.011
C8	0.015	C17	0.002		
C9	0.023	C18	0.088		

6. Measurement of New York City

The Statue of Liberty, the Empire State Building, and the Brooklyn Bridge are all landmarks in New York City. Therefore, we use the complete evaluation model established to score New York, and the results are shown in Table 4.

Table 4: Result table

	New York
Meteorological dimension	-0.157
Local basic situation dimension	-0.021
Cultural and artistic dimension	0.263
Total	0.085

Based on this evaluation coefficient, this paper puts forward relevant development suggestions to the New York City government:

1) New York City should focus on extreme weather prevention and control. By preparing for extreme weather, you can minimize damage.

2) The New York City government can increase investment in the protection of landmark buildings, including but not limited to increasing its financial budget.

3) When building tall buildings in New York City, attention should also be paid to improving the disaster resistance of buildings.

4) In order to better cope with the storm weather, the New York City government should do a good job in the urban drainage system.

7. Conclusion

In this paper, entropy weight method and analytic hierarchy process are used to measure the index weight of the evaluation system, and the least square method is used to obtain the optimal weight, and a complete insurance risk evaluation system based on extreme weather is constructed. Using this evaluation system to measure the relevant index of New York City, four suggestions are put forward for New York City government. The government should pay attention to the impact of extreme weather to ensure the development of local ecology and new quality productivity.

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