Insurance Underwriting Decision Study Based on Analysis of Extreme Weather Intensity

Jialei Song [*, #], Yueting Wang [#], Bin Li

Department of Automation, Northeast Electric Power University, Jilin, China, 132012

* Corresponding author: songjialei073@163.com

[#]These authors contributed equally.

Abstract. As global climate change intensifies and extreme weather events escalate in frequency and severity, the insurance industry faces significant challenges in risk assessment and underwriting strategies, highlighting the inadequacies of traditional approaches. This article presents a comprehensive study that addresses the urgent need to reconcile insurance companies' profitability with homeowners' ability to cope with increasing risks and losses. This study uses demographic and economic factors to assess the impact on insurance profitability and uses the TOPSIS algorithm to assess the profitability of insurance companies and formulate appropriate underwriting strategies. The analysis includes a comparative assessment of the forecast profitability and actual profitability of US and UK insurance companies in 2020. Their composite score index is greater than 0.2, and they all have the option of underwriting. Comparison with relevant data confirms the validity of the research. This article uses five indicators: population density, economic development level, the intensity of extreme weather events, community building resilience, and community service level to formulate decision-making plans. It uses the analytic hierarchy process (AHP) and consistency test to finally calculate a comprehensive scoring index. Determine the risk level of each region and provide targeted suggestions to insurance companies. In addition, a "property loss model" for future data prediction is developed to help insurance companies make profits and homeowners reduce losses, thereby achieving mutually beneficial results.

Keywords: Property damage model, TOPSIS, Insurance company decision model, Extreme Weather Intensity.

1. Introduction

As global climate change intensifies, the frequency and intensity of extreme weather events are on the rise, posing huge challenges to the social economy. Especially for the insurance industry, how to accurately assess the risk of extreme weather events and formulate reasonable underwriting strategies has become an urgent problem to be solved. Traditional risk assessment methods often fail to fully consider the complexity and uncertainty of extreme weather events [1], leading to deviations in insurance product design and pricing, which in turn affects the long-term stable development of insurance companies [2].

For this study, we started using the TOPSIS algorithm. TOPSIS is a multi-criteria decision analysis method originally developed by Ching-Lai Hwang and Yoon in 1981 [3] and further developed by Yoon in 1987 [4], and Hwang, Lai, and Liu, in 1993 year [5]. The TOPSIS algorithm is known for its practicality and flexibility in dealing with complex multi-criteria decision-making problems. Widely used in several fields, a study examines how the fuzzy TOPSIS framework can be used to select complex projects. The process helps provide weights to given criteria and rank alternatives to determine the optimal solution [6]. In the context of ETL software selection, TOPSIS is used in conjunction with the Analytical Hierarchy Process (AHP) to identify the most important criteria and sub-criteria that influence software selection issues [7]. One study used the fuzzy TOPSIS multi-criteria decision analysis algorithm to guide the purchase decision of dry bulk carriers [8].

In this study, data collection and processing were first conducted, using a property loss model to predict property losses under extreme weather in the next few years, and providing an analysis of insurance profitability combined with demographic and economic factors; and then combined with

real estate developers' strategy, the underwriting plan has been optimized, and development response strategies under the influence of extreme weather have been strengthened.

2. Considering the Impact of Population and Economic Factors on Insurance Profitability

The profitability of an insurance company is related to premium income and claim costs [9]. By considering the influencing factors of premium income and claim costs, the company's profitability can be indirectly derived. Premium income is related to factors such as local population density and economic level, and claims costs are related to factors such as the intensity of extreme weather events. Therefore, in this study, these three most important factors were taken, and the TOPSIS algorithm was used to calculate the comprehensive score of the output results. Index to judge the profitability of insurance companies and determine corresponding underwriting strategies.

2.1. Data collection and preprocessing

There are many types of extreme weather, and each type corresponds to different intensity indicators and occurs in inconsistent time intervals [10]. Therefore, the total amount of property damage caused by climate every year is used to measure the intensity of extreme weather. In this study, specific data on the amount of property damage caused by extreme weather in the UK and the United States over decades was obtained from the International Disaster Database (EM-DAT). The data was processed as follows: Check whether there are individual duplicate data points in the data, delete them for outlier processing; fill in missing data, and standardize the data. The reliability of this study is verified by comparing forecasts and actual data on insurance company profitability in the United States and the United Kingdom in 2020.

2.2. Forecasting the intensity of extreme weather events

The intensity of extreme weather events changes with time rather than being fixed, and the causes of non-stationary time series are random rather than deterministic [11]. Therefore, the Property damage model is used to predict future data.

The property damage model requires that the sequence satisfies stationarity. First, the ADF test needs to be performed to analyze whether it can significantly reject the hypothesis that the sequence is not stationary [12]. When the significance $P<0.05$, it means that the null hypothesis is rejected and the sequence is a stationary time series. Otherwise, it means that the sequence is an unstable time series.

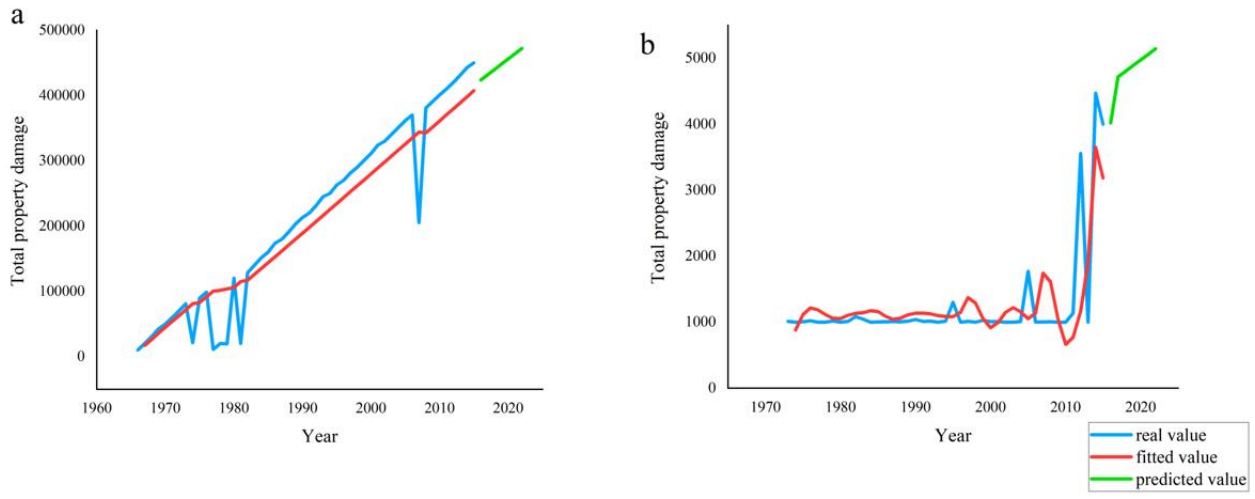


Figure 1. Results of property loss projections for the UK and the US

Figure 1 shows the prediction results of the United Kingdom and the United States using the Property damage model. In a, the United States data from 1966 to 2015 is analyzed, and the total

annual property losses in the United States in the next five years are predicted, goodness of fit $R^2 = 0.926$. In b, the UK data from 1973 to 2015 is analyzed, and the total annual property losses in the UK in the next five years are also predicted, goodness of fit $R^2 = 0.798$.

2.3. Insurance profitability and underwriting strategies

In this study, three indicators: population density, economic level, and intensity of extreme weather events were used to determine the profitability of insurance companies based on the TOPSIS algorithm [13]. To establish the TOPSIS model, you first need to trend the original data [14], which is generally a forward processing of the data. Among the three indicators in the model, population density and economic level are very large indicators, and the intensity of extreme weather events is a very small indicator. Therefore, the intensity of extreme weather events should be forwarded. Secondly, normalization is used to convert the actual value of each indicator into a dimensionless relative value [15], and then the weight of each indicator is determined based on expert scoring, the optimal solution is determined, and the distance between the data and the positive ideal solution and the negative ideal solution is calculated, to calculate the closeness of the evaluation object to the optimal solution, that is the comprehensive score index. When the comprehensive score index is greater than 0.2, the insurance company can choose to underwrite; when the comprehensive score index is less than 0.2, the risk of underwriting is greatly increased, and the insurance company should choose to refuse insurance. The specific results of the 2020 data analysis are shown in Table 1. A is the United States and B is the United Kingdom. Their comprehensive score index is greater than 0.2, so insurance can be selected in both regions. According to relevant data review, insurance companies made profits from underwriting in both countries in 2020, thus verifying the reliability of the research.

Table 1. Comprehensive score index

	Positive ideal solution distance (D+)	Negative ideal solution distance (D-)	Composite score index	Underwriting Strategy
A	0.83055595	0.54784382	0.39744915	acceptance criteria
B	0.5477225	0.83665978	0.60435601	acceptance criteria
C	0.82116132	0.20574626	0.20035519	acceptance criteria
D	0.89947981	0.1511713	0.14388344	Denial of coverage

3. Strengthening construction and development responses to extreme weather

In addition to population density, economic level, and intensity of extreme weather events, the underwriting strategy also needs to be adjusted according to the real estate developer's strategy and combined with the community's building flexibility, community service level, and other factors to determine a more reasonable underwriting plan.

3.1. Determination of various indicators

In this study, five indicators will be used to make decisions: population density, economic development level, intensity of extreme weather events, community building resilience, and community service level. Among them, the architectural resilience of a community is related to factors such as the design of the building, the materials used, and disaster resistance [16]; the level of community service is mainly related to the quality of infrastructure, greening level, medical level, etc. We choose disaster resilience to represent building resilience and infrastructure quality to represent community service levels.

The five indicators have different impacts on insurance companies' decisions, so they need to be quantified and their weights determined. Here, the weight of each indicator is determined through the analytic hierarchy process (AHP) [17]. The results of the analytic hierarchy process are as follows.

Table 2. AHP hierarchical analysis results

items	eigenvector (math.)	Weight value (%)	Maximum characteristic root	CI value
population density	0.266	5.314	5.26	0.065
Economic level	1.124	22.488		
The intensity of extreme weather	2.633	52.659		
Architectural resilience	0.605	12.099		
Level of community service	0.372	7.411		

- Consistency check

According to the analysis results, the CI value is 0.065. According to the RI table, the corresponding RI value is 1.11. According to .1, it passes the consistency test.

The weight calculation results of various indicators show that the weight of population density is 5.314%, the weight of Economic level is 22.488%, the weight of the intensity of extreme weather is 52.659%, the weight of Architectural resilience is 12.099%, and the weight of Level of community service is 7.441%.

3.2. Scoring decision-making

Based on 5 indicators, the TOPSIS algorithm is used to score different regions and specify corresponding underwriting strategies. Except for the intensity of extreme weather events, which is a very small indicator, the other four indicators are all very large. Therefore, the intensity of extreme weather events needs to be forwarded before the comprehensive score index can be calculated. The results are as follows.

Table 3. Comprehensive score index and corresponding strategies

	Positive ideal solution distance (D+)	Negative ideal solution distance (D-)	Composite score index	Underwriting Strategy
Area 1	0.16850073	0.89064424	0.84090872	High-priority development
Area 2	0.94745883	0.07324159	0.0717562	Denial of coverage
Area 3	0.75310402	0.52611396	0.4112778	low-priority development
Area 4	0.58722058	0.77288743	0.56825445	Medium-priority development

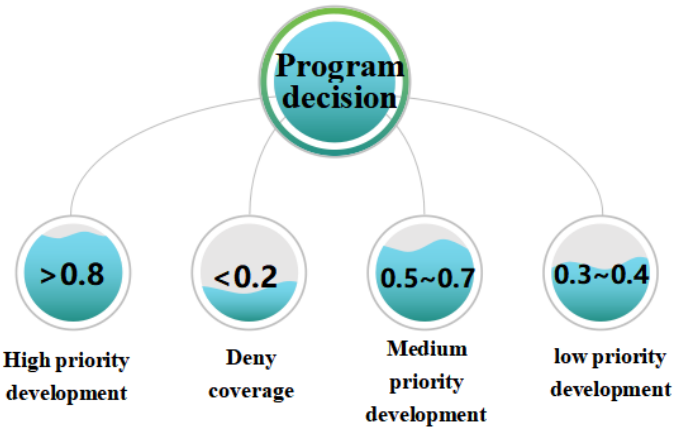


Figure 2. Underwriting decision scenarios

The risk levels of different regions are determined based on their comprehensive scoring index. Figure 2 shows the specific level division. Based on the division, this study provides insurance companies with the following solutions:

(1) For areas with extremely high risks, to avoid large claims from insurance companies, it is recommended that they refuse coverage.

(2) For areas with higher risks and low-priority development, premiums can be relatively increased, reinsurance protection can be increased, or specific risk products such as earthquake insurance and flood insurance can be developed to meet the insurance needs of local customers, thereby expanding market share and ensuring a balance between risk and return.

(3) For medium-risk areas and medium-priority development, the company can also maintain profitability by relatively increasing premiums or increasing reinsurance protection.

(4) For areas with low-risk levels, the probability of profit is greatly improved, and insurance can be insured with confidence.

4. Conclusion

In this study, through quantitative analysis of the intensity of extreme weather events, property losses under extreme weather events were used to replace their intensity, combined with historical data, and a property loss model was used to predict future trends. Taking it and the region's economic level and population density as indicators, the TOPSIS algorithm is used to obtain a comprehensive score index. Based on this, the insurance company is provided with a preliminary underwriting decision-making plan. Its feasibility was verified through historical data from the United States and the United Kingdom. Then, combined with the building flexibility and community service level of real estate development, the analytic hierarchy process was used to obtain the weight of each indicator and further provide a more specific underwriting decision-making plan.

This article provides a research idea and framework that can be applied to risk assessment-related fields. The experimental results show that the insurance underwriting decision-making scheme has good predictability and feasibility, and has certain practical application value.

References

[1] GROUP B C. An Insurance Risk Framework for Climate Adaptation [J]. 2023.

[2] GEBREMICHAEL E, MOLTHAN A L, BELL J R, et al. Flood hazard and risk assessment of extreme weather events using synthetic aperture radar and auxiliary data: A case study [J]. Remote Sensing, 2020, 12 (21): 3588.

[3] OZTURK D, BATUK F. TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION (TOPSIS) FOR SPATIAL DECISION PROBLEMS [J]. 2021.

[4] ZEYAEYAN S, FATTAHI E, RANJBAR A, et al. Classification of Rainfall Warnings Based on the TOPSIS Method [J]. Climate, 2017, 5 (2).

[5] SAWYERR B A, FASINA E, ADEDEJI W O, et al. A fuzzy TOPSIS method for surface integrity criteria ranking using the wire electrical discharge machining process [J]. Journal of Engineering and Applied Science, 2023, 70 (1).

[6] SHAMSUZZOHA A, PIYA S, SHAMSUZZAMAN M. Application of fuzzy TOPSIS framework for selecting a complex project in a case company [J]. Journal of Global Operations and Strategic Sourcing, 2021, 14 (3): 528 - 66.

[7] HASNAIN S, ALI M K, AKHTER J, et al. Selection of an industrial boiler for a soda-ash production plant using analytical hierarchy process and TOPSIS approach [J]. Case Studies in Thermal Engineering, 2020, 19: 100636.

[8] SAHIN B, YIP T L, TSENG P-H, et al. An Application of a Fuzzy TOPSIS Multi-Criteria Decision Analysis Algorithm for Dry Bulk Carrier Selection [J]. Information, 2020, 11 (5).

[9] MARKONAH M, RIWAYATI H E, KUMALASARI R. The effect of premium income, expenses claim, and underwriting on the profitability of Indonesia joint enterprises insurance companies [J]. Jurnal Siasat Bisnis, 2023: 219 - 34.

[10] VAN OLDENBORGH G J, VAN DER WIEL K, KEW S, et al. Pathways and pitfalls in extreme event attribution [J]. Climatic Change, 2021, 166 (1-2).

[11] RYAN O, HASLBECK J, WALDORP L. Non-stationarity in time-series analysis: Modeling stochastic and deterministic trends [J]. 2023.

[12] MODARONE. Leverage ADF tests to model time series [J]. Times Finance, 2010, (4X): 46 - 8.

[13] HU K, WANG R, XU J, et al. Extreme analysis of typhoon disaster in mainland China with insurance management [J]. International Journal of Disaster Risk Reduction, 2024, 106: 104411.

[14] ZHAO D, LI C, WANG Q, et al. A comprehensive evaluation of national electric power development based on cloud model and entropy method and TOPSIS: A case study in 11 countries [J]. Journal of Cleaner Production, 2020, 277.

[15] MUKHAMETZYANOV I Z. ReS-Algorithm for Converting Normalized Values of Cost Criteria into Benefit Criteria in MCDM Tasks [J]. International Journal of Information Technology & Decision Making, 2020, 19 (05): 1389 - 423.

[16] AMIRZADEH M, BARAKPOUR N. Strategies for building community resilience against slow-onset hazards [J]. International Journal of Disaster Risk Reduction, 2021, 66: 102599.

[17] KARIM R, KARMAKER C. Machine selection by AHP and TOPSIS methods [J]. American Journal of Industrial Engineering, 2016, 4 (1): 7 - 13.