Problem Chosen	2024	Team Control Number
E	**MCM/ICM Summary Sheet**	**2424912**

Facing natural disasters: Forecast and Evaluation

Summary

Mysterious temples, towering buildings, historic museums...Landmarks often carry the soul of the city, nourish the hearts of citizens. Unfortunately, with the frequency of extreme weather, countless buildings are lost in wildfires, hurricanes, and floods. The extreme weather endangers the landmarks and the residents' personal and property safety. We conduct research on extreme weather and landmarks to better protect the rights of residents and buildings.

Several models are established: Model I: Risk Prediction and Evaluation Model; Model II: Property Valuation and Construction Model; Model III: Landmark Value Appraisal.

Prepare for establishing models, we analyzed the main types of natural disasters and their main impact modes. The large amount of data obtained from the government will be processed and visualized to establish the target direction of our future research.

For Model I: Through consulting a large number of official data and literature, the two concepts of insurance cost and insurance loss are obtained, and constructed the insurance model to calculate the insurance range. Meanwhile we've five evaluation indicators to define the **climate risk value(CvaR)**, and build a **grey prediction model** to predict the probability of occurrence and economic loss in the next year. Then, we selected two representative regions to substitute into the model and obtained their insurance models as follows: **1424$~2929$, 1507$~3103$.**

For Model II: we used **arcgis spatial modeling idea** to build a model to evaluate the construction and development value of a certain area. We determined the five evaluation indicators of **population, economy, geographical environment, market saturation, policies and regulations**, then combined with the **natural risk value** defined in Model I to select the appropriate construction area. Then, we put Louisiana into the model, gave the suitable areas for construction, and visualized the results.

For Model III: According to the four primary indexes of historical, cultural and economic communities, a total of eight secondary indexes are determined as the evaluation indexes of landmark value, and the buildings in each area are evaluated by **topsis entropy weight method**. At the same time, three kinds of protection measures are established by consulting the data, and then the impact of different protection measures on the value model is considered, so assumed α、β、γ、δ four weight coefficients to obtain the comprehensive value assessment.

Finally, we chose the American World War II Museum as the research building, and selected another nine reference buildings as the data set for training. First of all, we judge that the World War II museum is a landmark through training, and **its comprehensive score is 0.1814**, which is between the two landmarks that have been moved. Therefore, we suggest that the World War II museum choose the protection measures for relocation. We then wrote a letter of suggestion, giving the community some suggestions on relocation planning, timing, and cost estimates.

In addition, we also conducted **sensitivity analysis** of CVaR risk coefficient model, That means Our models provide an accurate risk assessment within a reasonable range of changes in insurance coverage.

Keywords: Climate risk value(CvaR); Arcgis spatial model; Topsis entropy weight method

Contents

1 Introduction

1.1 Problem Background

Figure1: Wildfire occurrence

On 25 April 2015, a magnitude 8.1 earthquake struck Nepal, causing heavy casualties. The most heartbreaking scene of destruction was the extensive destruction of Durbar Square, a famous World Heritage site in Kathmandu. Two-thirds of the buildings in the historic square have collapsed.

The Nepal earthquake is a stark reminder of the relentless threat posed by natural disasters in recent years. Earthquakes, wildfires, tsunamis and other disasters have brought human tragedy in succession, highlighting the vulnerability of our societies to the forces of nature. These disasters have a profound impact not only on human security, but also on socio-economic stability and cultural heritage.

Dealing with the consequences of natural disasters requires a multifaceted approach. Disaster risk assessment becomes a critical step, requiring an understanding of the factors that contribute to a region's vulnerability. These factors include geological stability, quality of infrastructure, level of community preparedness and effectiveness of early warning systems. In addition, the protection of cultural heritage in the face of natural disasters also faces a series of challenges. Protecting monuments, artefacts and heritage sites from destruction is essential to preserving the historical character and cultural continuity of affected communities.

1.2 Restatement of the Problem

Assessing the degree of risk from natural disasters is a complex issue that requires us to consider multiple indicators. In order to analyze and determine the degree of natural disaster risk in different regions, taking into account the background information, we need to undertake the following work:

- Establish a model to assess the degree of risk of different kinds of natural disasters. Assess the risk level of two areas on different continents that experience extreme weather events by our model. [1]
- Establish a preservation model to determine what measures should be taken to preserve buildings in community.
- Select a historic landmark that may experience extreme weather events and apply above two models to assess the value of this landmark.
- Compose a one-page letter, including a plan, timeline, and cost proposal for the future of this treasured landmark.

1.3 Our Work

This problem requires us to quantify the impact of natural disasters and build models to mitigate the impact on insurance companies and communities. In order to avoid complex description and more directly reflect our working process, the flow chart is as figure 2:

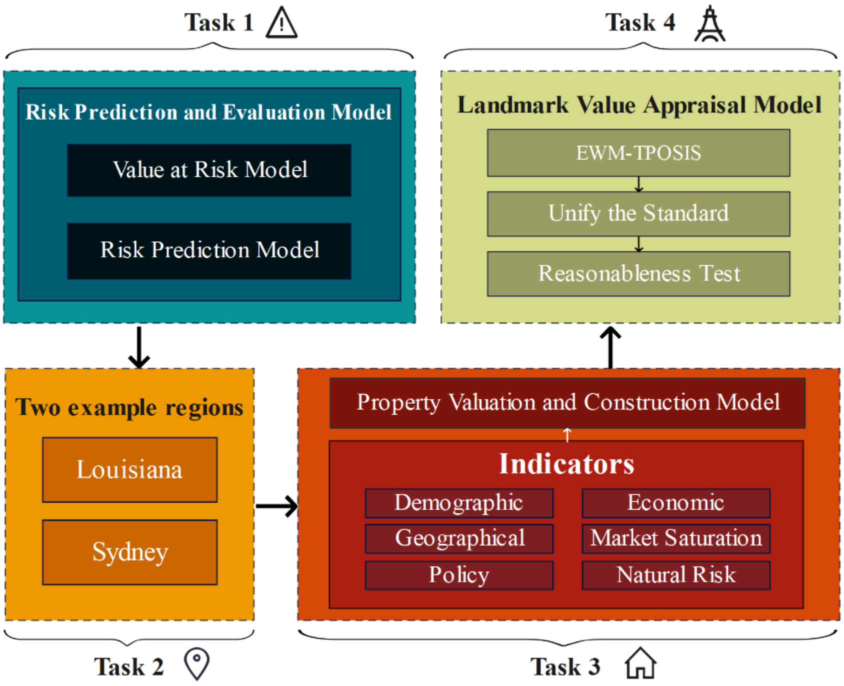


Figure 2: Flow chart of our work

2 Assumptions and Justifications

Since real-world problems always involve many complex factors, first we need to make reasonable assumptions to simplify the model, and each assumption is followed by the corresponding explanation:

Assumption 1: Natural disasters occur independently of each other.
Justification: The occurrence of natural disasters is affected by a variety of factors, and we do not believe that any two natural disasters are directly related.

Assumption 2: Sydney's drought disaster follows the Poisson distribution
Justification: Sydney's droughts are rare and memoryless.

Assumption 3: All insurance was sold.
Justification: It might not happen this way in real life, but it can simplify our calculations and help us come up with strategies.

Assumption 4: The secondary indicators are independent of each other.
Justification: Optimize unnecessary calculations to facilitate model building.

3 Notations

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

Table 1: Notations used in this paper

Symbol	Description	Unit
ITL	total loss of the insurance company	
RTL	total loss of the region	
ICP	proportion of guarantee of the insurance company	
PIQ	property insurance quotation	
EL	economic loss	
P	precipitation	Inch(es)

F	flood	
WS	wind speed	mph
S	storm	
WF	wildfire	

4 Model Preparation

4.1 Common Natural Disaster

After consulting a large amount of data, we selected four natural disasters with high frequency and great loss, which are shown in the figure 3, and also provide conceptual support for subsequent research.[2]

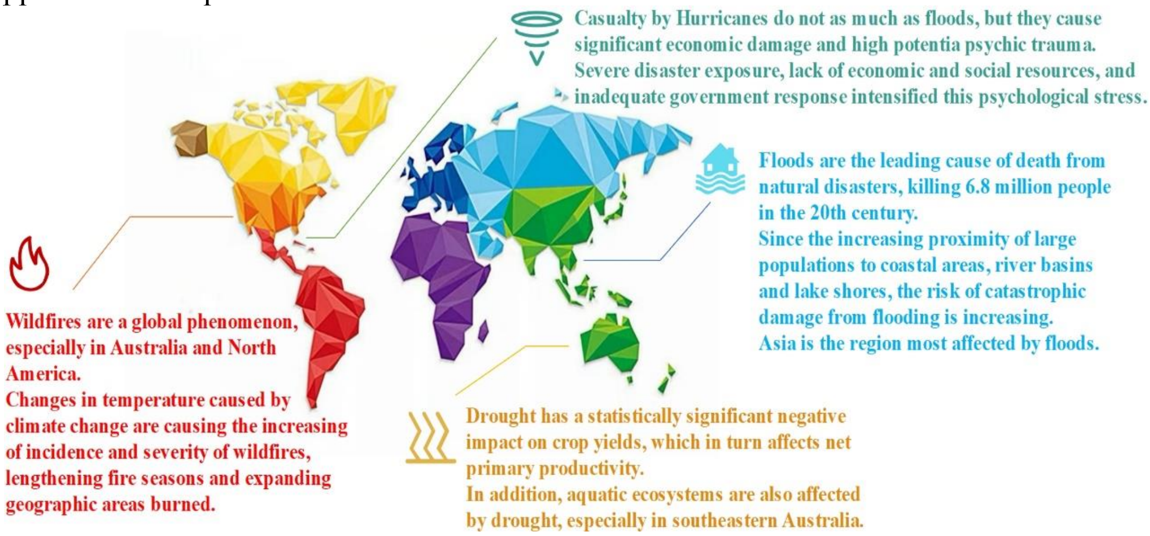


Figure 3: Four common natural disasters

4.2 Data Preprocessing

Data is not provided directly to us, so we need to decide what data to collect. Through the analysis of the problem, we collected the main data in Table 2.

To get future trends of natural disasters such as storms, floods, and wildfires, we counted the number of different types of natural disasters and their total losses over the past ten years. Some of the data were missing and we used linear interpolation to fill them in. Here is the data after filling in:

Table 2: Natural conditions and frequency of natural disasters of Louisiana

Economic Loss	Year	Precipitation (inches)	Flood	Wind Speed (mph)	Storm	Wildfire	Property Insurance Quotation
0.86	2014	0.15	1	9.47	6	42	18667
0.87	2015	0.17	2	9.18	6	44	18286
0.90	2016	0.20	4	9.02	8	43	18905
0.90	2017	0.20	2	9.75	10	44	19662
1.20	2018	0.18	0	9.60	9	43	19294
1.10	2019	0.18	3	9.64	8	45	19946
1.30	2020	0.16	0	9.74	13	45	20051
1.50	2021	0.19	2	9.21	11	45	19880
1.65	2022	0.14	0	9.42	8	45	20158

5 Risk Prediction and Evaluation Model (RPE Model)

In this section, we develop a **risk prediction assessment model** to enhance the sustainability of the property insurance industry. Firstly, the grey prediction model is used to predict the probability of different kinds of natural disasters in the next year by the occurrence of natural disasters in a certain area in the past ten years. At the same time, considering the low frequency of natural disasters, the number of times is predicted in the unit of year, and then the probability of natural disasters occurs every day is calculated. After obtaining the probability of occurrence of natural disasters, we calculate the total loss of the insurance company(ITL) when natural disasters happen (through the total loss of the region(RTL) under the effect of natural disasters and the proportion of guarantee of the insurance company(ICP)). Then we obtain the insurance cost from the number of insured people in the region, and uses the principle that the cost is greater than or equal to the loss to get the quotation(Q).

And finally, we built a **Value at Risk Model** to quantify the level of financial risk within a firm or investment portfolio over a specific time frame. For insurance purposes, especially in the context of extreme weather events, a similar metric could be adapted, which we might call Climate Value at Risk (CVaR)[3]. This metric would aim to estimate the amount of potential loss due to climate-related risks that a policy holder could face.

5.1 Data Description

After reviewing a large number of studies and literatures, we selected the three natural disasters with the most representative and extensive coverage, namely, hurricane, flood and wildfire, and obtained the occurrence times of these three natural disasters in the past ten years by consulting the data to facilitate the later calculation of frequency.

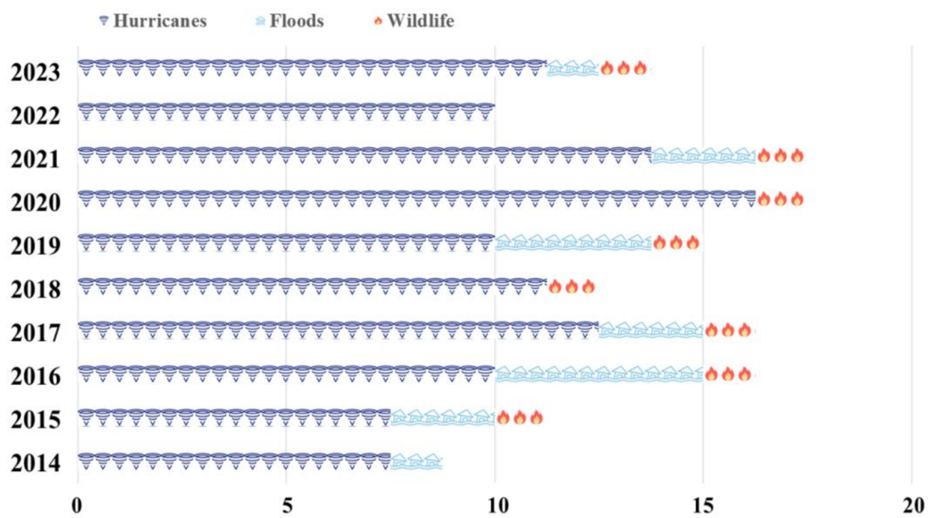
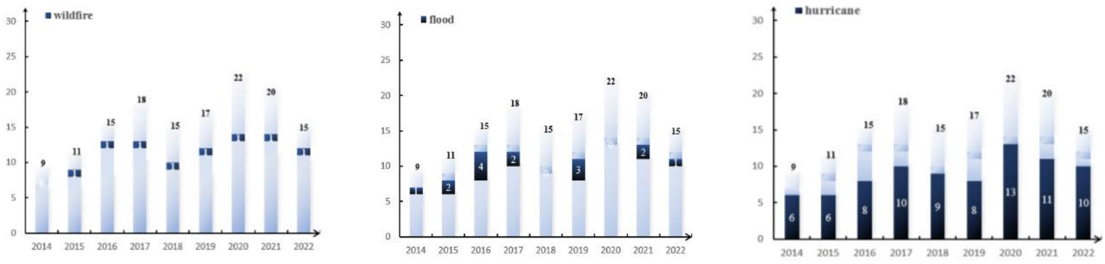


Figure 4: Number of natural disasters in the past decade

Then, in order to calculate the loss that insurance companies need to bear when natural disasters occur, we looked up the total loss amount generated when three kinds of natural disasters occur, and did visualization processing.



(a) Loss of wildfire **(b) Loss of floods** **(c) Loss of hurricanes**

Figure 5: Loss of three kinds of natural disasters

From the figure 5, we can see that the sum of the monetary losses caused by the occurrence of three natural disasters, wildfire, hurricane and flood, accounts for a large proportion, which provides data support for us to predict the monetary losses in the next year.

5.2 The Establishment of RPE Model

5.2.1 Risk Prediction Model

According to the small amount of our data set and the time-related characteristics, we adopted a gray prediction model. In SPSS, we imported three groups of pre-processed data respectively, including the number of natural disasters occurring in the past ten years, and then obtained the prediction result of the number of occurrences in the next year after operation. The result was divided by the number of days in a year, which is the probability we needed.

Table 3: Original Data Preprocessing

Year	Floods	Hurricanes	Wildfire	Economic Loss
2014	0.0000	0.1400	0.3017	0.2347
2015	0.1824	0.1400	0.3139	0.2370
2016	0.1826	0.2801	0.3067	0.2456
2017	0.0000	0.1400	0.3125	0.2456
2018	0.1826	0.2801	0.3118	0.3275
2019	0.1826	0.4201	0.3197	0.3002
2020	0.3651	0.4201	0.3218	0.3547
2021	0.5477	0.2801	0.3232	0.4093
2022	0.3651	0.4201	0.3247	0.4503
2023	0.5477	0.4201	0.3254	0.2729

5.2.2 Calculation of Insurance Cost and Insurance Loss

The multi-index model incorporates multiple risk factors, each with their own independent probabilities and impacts, and may involve sensitivity analysis to determine the influence of each factor on the overall risk.

The original formula for the loss of insurance and cost of insurance are:

$$Cost\ of\ insurance = m \times N \tag{1}$$

$$Loss\ of\ insurance = P \times (P_1 \times M_1 + P_2 \times M_2 + P_3 \times M_3) \tag{2}$$

$$Cost\ of\ insurance \geqslant Loss\ of\ insurance \tag{3}$$

The result obtained from the above formula is our minimum insurance cost, and we also need to obtain an insurance upper limit to ensure that the insurance method is reasonable, so we consider multiplying an insurance coefficient before the original insurance cost, so that it is still greater than or equal to the insurance loss. If it is not established, that is, our insurance upper limit

$$Loss\ of\ insurance \geqslant f_i\ Cost\ of\ insurance \tag{4}$$

$$P \times (P_1 \times M_1 + P_2 \times M_2 + P_3 \times M_3) \geqslant f_i \times m \times N \tag{5}$$

$$f_i \leqslant \frac{P(P_1 \times M_1 + P_2 \times M_2 + P_3 \times M_3)}{m \times N} \tag{6}$$

where:

- P_1, P_2, P_3 are the probabilities of different natural disasters,
- M_1, M_2, M_3 are the losses borne by insurance companies in the event of natural disasters,
- N is the total number of insurance policies,
- m is the amount of each insured person
- P is the insurance company shall pay the total amount of loss

5.2.3 Value at Risk Model

We define **climate risk Value (CVaR)** with the following components:

- **Climate Event Probability (CeP):** The likelihood of a specific climate event occurring within a given time frame.
- **Climate Event Severity (CeS):** The potential severity of an event, usually quantified by the maximum expected loss.
- **Climate Event Exposure (CeE):** The exposure of the insured asset to a specific climate event.
- **Insurance Coverage (ICR):** The ratio of the amount insured to the value of the insured asset.
  Mitigation effectiveness factor (MEF): The effectiveness of existing mitigation measures, such as early warning systems, infrastructure resilience, and emergency response plans.

we use indicators to quantify and assess the risk comprehensively. For Climate Event Probability (CeP), it reflects the likelihood of a specific weather event occurring. Climate Event Severity (CeS) indicates the potential impact and cost associated with an event. Climate Event Exposure (CeE) relates to the degree of exposure or susceptibility of assets to the identified climate events. The Insurance Coverage Ratio (ICR) represents the portion of potential losses covered by insurance.[4]

Incorporating the concept of Mitigation Effectiveness Factor (MEF) as a balance between an area's resilience and community vulnerability offers a nuanced approach to risk assessment. We suppose that MEF can be seen as a dynamic interplay between the adaptive capacities of a region to withstand and recover from climate events (resilience) and the inherent susceptibility of the community to suffer harm (vulnerability). This reflects a comprehensive understanding that resilience efforts can substantially mitigate, but not entirely eliminate, the risks posed by climate events due to underlying vulnerabilities.

So, we have

$$MEF_i = Resilience - Vulnerability_i \tag{7}$$

Then, the CVaR for an insurance policyholder could then be calculated as:

$$CVaR = \sum_{i=1}^{n} CeP_i \times CeS_i \times CeE_i \times (1 - ICR_i \times (Resilience_i - Vulnerability_i)) \tag{8}$$

Next, we divide the objective parameters in detail in figure 6.

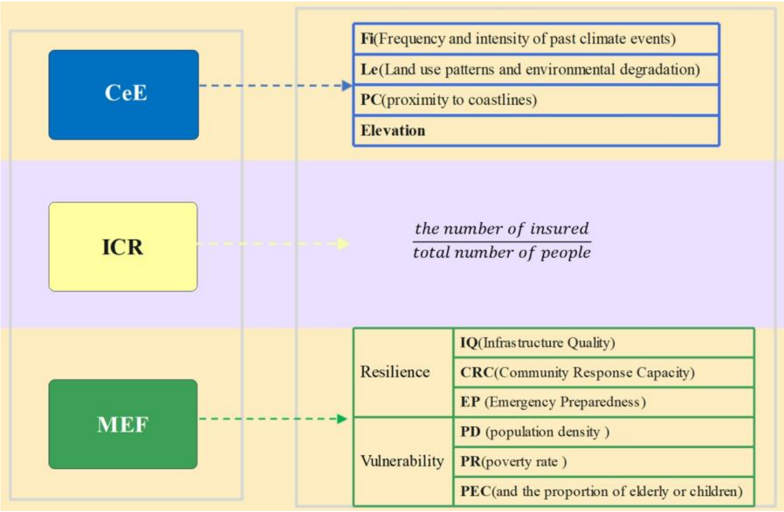


Figure 6: Further explanation of CeE, ICR and MEF

So, the Risk Index can be expressed:

$$Riskindex = \frac{CVaR}{Total\ economic\ loss} \times 100\% \tag{9}$$

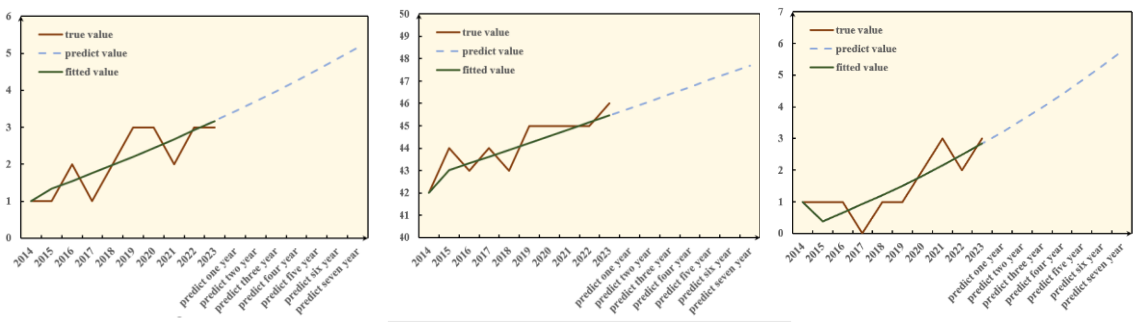
5.3 The Solution of RPE Model

We selected two regions with a relatively high concentration of natural disasters, namely Louisiana in the United States and Sydney in Australia. Both regions are prone to floods and wildfires. Meanwhile, Louisiana has the characteristics of more hurricanes, while Sydney has the characteristics of frequent droughts.

5.3.1 Louisiana

Through the risk prediction model, we get the number and probability of hurricanes, floods and wildfires occurring in the next year as follows:

$$P_1 = \frac{3}{365} = 0.00821918, \quad P_2 = \frac{46}{365} = 0.126027, \quad P_3 = \frac{3}{365} = 0.00821918$$

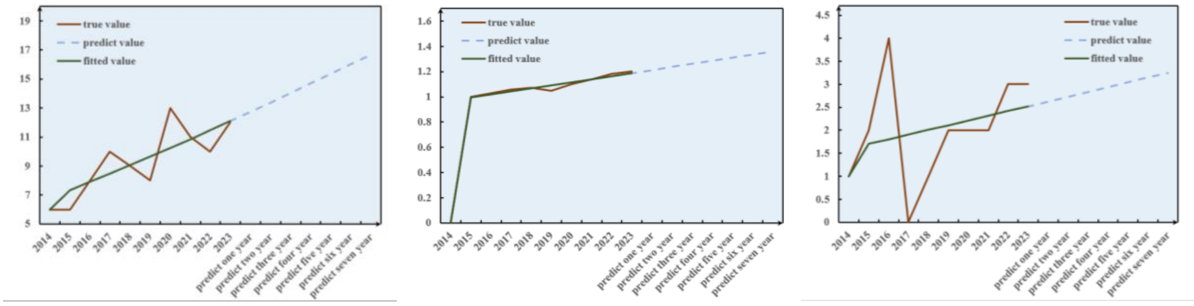


(a)Number of hurricanes **(b)Number of wildfire** **(c)Number of floods**

Figure 7: Prediction of the number of natural disasters in Louisiana

At the same time, we also forecast the total losses caused by natural disasters in the next year, which are:

$$M_1 = 12.72,\quad M_2 = 1.21,\quad M_3 = 2.62$$



(a)Loss of hurricanes **(b)Loss of wildfire** **(c)Loss of floods**

Figure 8: Prediction of the loss of natural disasters

Through a large number of sources, we have obtained the relevant specific data for Louisiana, this includes the upper and lower limits of the insurance company's payout ratio $P_{\min} = 10\%$ and $P_{\max} = 20\%$, as well as the total number of $N = 190000$ insured people in Louisiana. We set the payout ratio into a range of $10\%\sim20\%$, and then divided it into five ranges of $10\%\sim12\%,\ 12\%\sim14\%,\ 14\%\sim16\%,\ 16\%\sim18\%,\ 18\%\sim20\%$ to get the insured amount range into the formula to generate the insurance plan .

Then we use the formula mentioned above to calculate:

$$Loss\ of\ insurance \geqslant Cost\ of\ insurance \tag{10}$$

$$\begin{aligned} m \times N &\leqslant P_{\min} \times (P_1 \times M_1 + P_2 \times M_2 + P_3 \times M_3) \\ m \times N &\geqslant P_{\max} \times (P_1 \times M_1 + P_2 \times M_2 + P_3 \times M_3) \end{aligned} \tag{11}$$

According to the calculation, we can give the insurance plan in Louisiana:

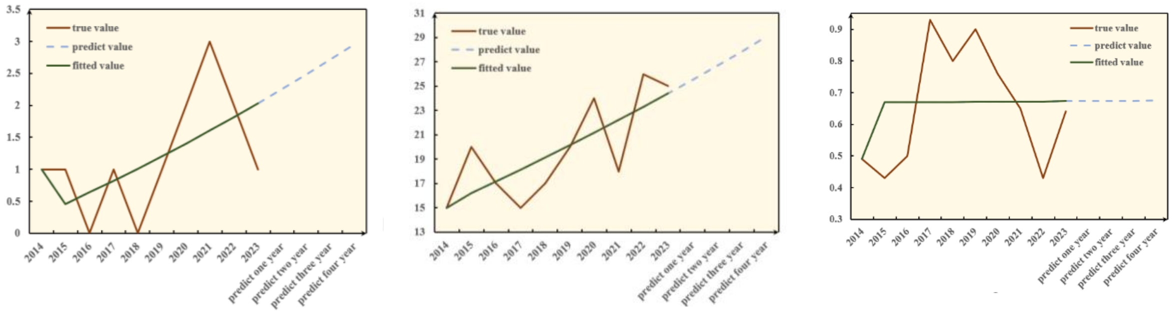
Table 4: Louisiana's insurance program suggests

Region	Insurance payout percentage	quoted price	Commitment range
Louisiana	$10\% \leqslant P \leqslant 12\%$	$1464\ \$ \leqslant m \leqslant 1767\ \$$	**$1464\ \$ \leqslant m \leqslant 2929\ \$$**
	$12\% \leqslant P \leqslant 14\%$	$1767\ \$ \leqslant m \leqslant 2050\ \$$	
	$14\% \leqslant P \leqslant 16\%$	$2050\ \$ \leqslant m \leqslant 2343\ \$$	
	$16\% \leqslant P \leqslant 18\%$	$2343\ \$ \leqslant m \leqslant 2636\ \$$	
	$18\% \leqslant P \leqslant 20\%$	$2636\ \$ \leqslant m \leqslant 2929\ \$$	

5.3.2 Sydney

Through the risk prediction model, we get the number and probability of drought, floods and wildfires occurring in the next year as follows, due to the particularity of drought, we use a value between 0 and 1 to measure the degree of drought, 0 means no drought, 1 means that the region has experienced major drought, so the value obtained by using the gray prediction model[5] is the degree of drought in the next year.

$$P_1 = \frac{3}{365} = 0.00821918,\quad P_2 = \frac{26}{365} = 0.0712329,\quad P_3 = 0.67$$

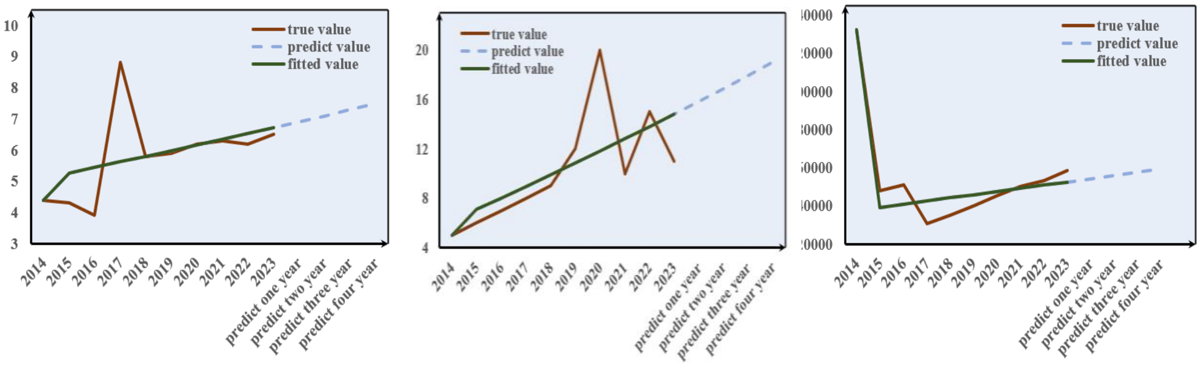


(a)Number of floods **(b)Number of wildfire** **(c)Number of droughts**

Figure 9: Prediction of the number of natural disasters in Syndey

Unlike Louisiana, the drought in Sydney lasted for a longer period of time. When discussing the total loss in Sydney, we use the sum-sum formula to get the sum of the loss suffered by the natural disasters:

$$M_1 = 15.83, \quad M_2 = 6.91, \quad M_3 = 0.0005424$$



(a)Loss of floods **(b)Loss of wildfire** **(c)Loss of droughts**

Figure 10: Prediction of the loss of natural disasters

Through a large number of sources, we have obtained the relevant specific data for Louisiana, this includes the upper and lower limits of the insurance company's payout ratio $P_{\min} = 10\%$ and $P_{\max} = 20\%$, as well as the total number of $N = 2560000$ insured people in Sydney. We set the payout ratio into a range of $10\% \sim 20\%$, and then divided it into five ranges of $10\% \sim 12\%,\ 12\% \sim 14\%,\ 14\% \sim 16\%,\ 16\% \sim 18\%,\ 18\% \sim 20\%$ to get the insured amount range into the formula to generate the insurance plan.

Then we use the same formula mentioned above to calculate:

$$Loss\ of\ insurance \geqslant Cost\ of\ insurance \tag{12}$$

$$\begin{aligned} m \times N &\leqslant P_{\min} \times (P_1 \times M_1 + P_2 \times M_2 + P_3 \times M_3) \\ m \times N &\geqslant P_{\max} \times (P_1 \times M_1 + P_2 \times M_2 + P_3 \times M_3) \end{aligned} \tag{13}$$

According to the calculation, we can give the insurance plan in Sydney:

Table 5: Sydeny's insurance program suggests

Region	Insurance payout percentage	Quoted price	Commitment range
Sydney	$10\% \leqslant P \leqslant 12\%$	$1507\ \$ \leqslant m \leqslant 1808\ \$$	**1507 $ ≤ m ≤ 3013 $**
	$12\% \leqslant P \leqslant 14\%$	$1808\ \$ \leqslant m \leqslant 2109\ \$$	
	$14\% \leqslant P \leqslant 16\%$	$2109\ \$ \leqslant m \leqslant 2411\ \$$	
	$16\% \leqslant P \leqslant 18\%$	$2411\ \$ \leqslant m \leqslant 2712\ \$$	
	$18\% \leqslant P \leqslant 20\%$	$2712\ \$ \leqslant m \leqslant 3013\ \$$	

5.4 The Extension of RPE Model

Besides, we use another way to calculate the insurance quotation. Considering the strong direct correlation between insurance quotation and year (the Pearson correlation coefficient between insurance quotation and year is 0.91), we use time series forecasting.

After verifying the data as stationary series, we obtained the values of p and q from the ACF and PACF graphs, and finally established ARIMA(2,0,2) model with SPSS.

Our forecast insurance quotation for 2024 is 21316, R^2 is 0.915, which means our model is a good fit.

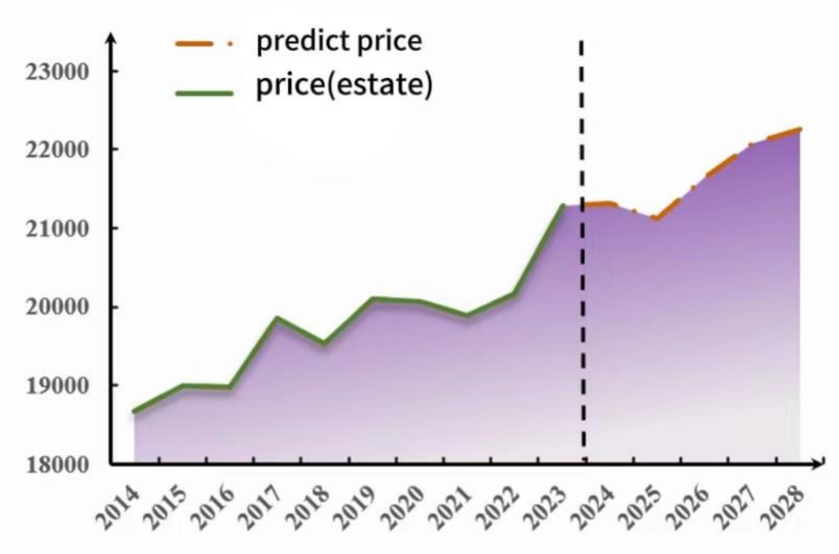


Figure 11: The development and forecast trend of insurance quotation

As can be seen from the figure 11, the insurance quotation increases year by year with the passage of time, so in the future rough calculation, we can also predict the insurance quotation of the next year according to the development trend of the quotation.

6 Property Valuation and Construction Model (PVC Model)

In this section, we use arcgis spatial modeling idea to build a spatial model to evaluate the construction and development value of a certain area. The following image are our main steps.

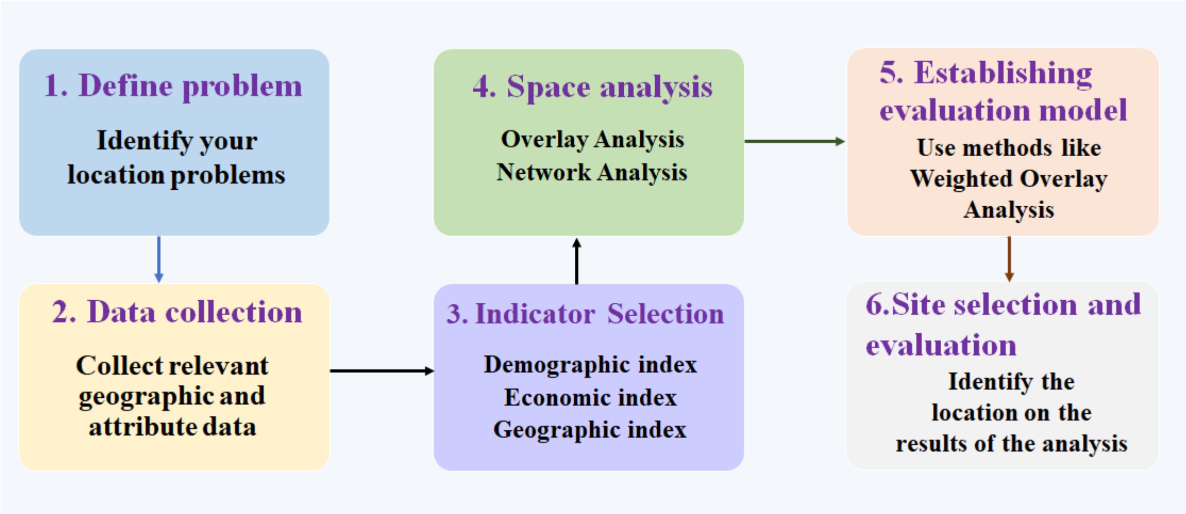


Figure 12: Flow chart of arcgis model

6.1 The Establishment and Data Description of PVC Model

After consulting a large amount of literature, we selected the appropriate indicators, which are, and take Louisiana as an example. In order to make it easier to display the results, we selected five relatively representative regions for display in the following description:

- Demographic indicators

  population density, age distribution, income level

In terms of population indicators, we chose the population density of Louisiana as the evaluation index. We searched the population numbers and occupied areas of all regions in Louisiana and obtained the population density. The results are shown as follows：

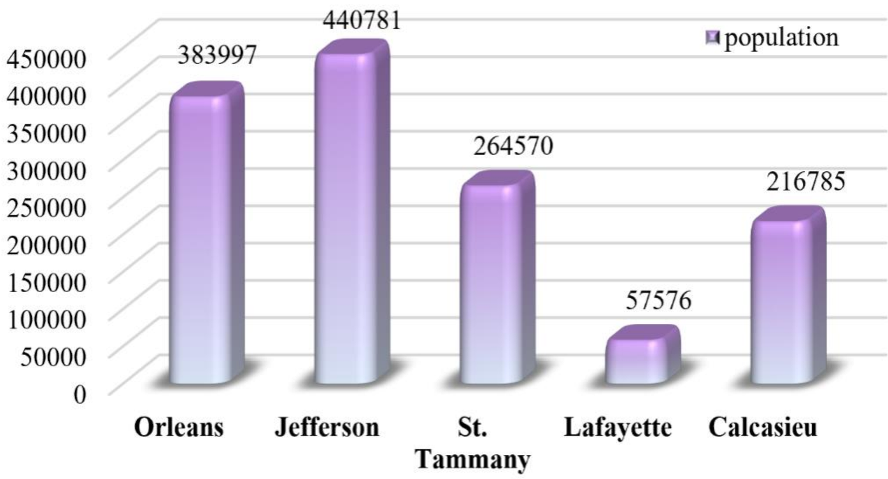


Figure 13: Represents the population of the area

We know that the size of the population growth rate is related to whether the area is suitable for construction, so to judge whether an area is suitable for construction, we can consider a simplified **population growth model.**[6]

The number of population increases can be given by the following formula:

$$P' = P(t+1) - P(t) = B - D + I - E \tag{14}$$

Where

-$P(t)$ is the number of people in time t

-B is the birth rate (number of births per unit time)
-D is the mortality rate (number of deaths per unit of time)
-I is the migration rate (number of people moving in per unit time)
-E is the migration rate (number of people moving out per unit time)

For a more accurate analysis, we need to further express the population growth rate, taking into account the change in time, the formula is:

$$r = \frac{P(t+1) - P(t)}{P(t)} = \frac{B - D + I - E}{P(t)} \tag{15}$$

Suitable construction criteria

If $r > 0$ indicates that the population is growing and may indicate increased demand in the area suitable for new construction projects.

- **Economic indicators**: employment rate, business activity, regional economic development level.[7]

In the economic indicators, we choose the annual per capita income of each parish as the evaluation standard, the unit is US dollars, and the results are shown as follows：

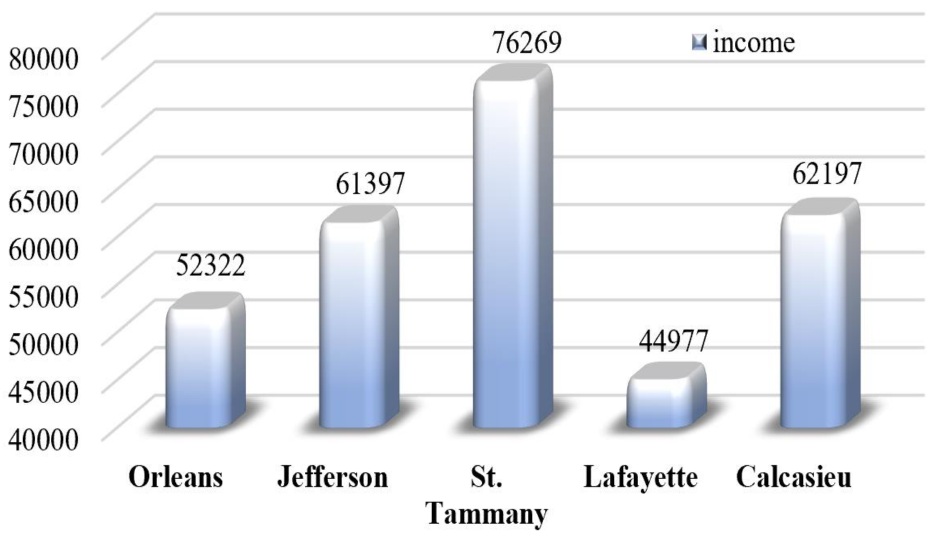


Figure 14: Represents the annual per capita income of the region

Per capita annual income can largely reflect the economic situation of a certain region, so the higher the per capita income on the graph, the higher the economic level of the region.

- **Geographical and environmental indicators**: topography, landform, accessibility (distance from major roads or transportation hubs)
- **Competition and market saturation indicators:** distribution of existing similar facilities, market demand and supply analysis

In terms of facilities construction in Louisiana, we studied the occupancy rate by region. A high occupancy rate may reflect the relative ease with which residents of a region own their own property. The relationship between the occupancy rate and market supply and demand can be analyzed by looking at indicators such as housing prices, construction activity, housing vacancy rate, and affordability.

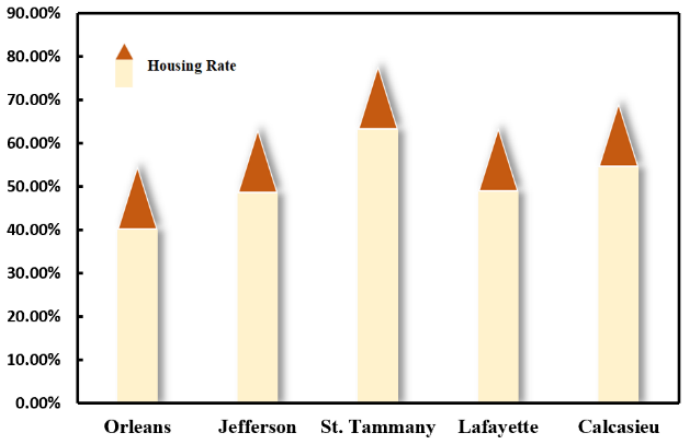


Figure 15: Represents the occupancy rate of the area

A high occupancy rate may reflect the relative ease with which residents of a region own their own property.

- **Policy and regulatory factors:** land use, planning restrictions, environmental protection areas
- **Natural risk factor:** A risk factor that we discussed in the last model

$$CVaR = \sum_{i=1}^{3} CeP_i \times CeS_i \times CeE_i \times (1 - ICR_i \times MEF_i) \tag{16}$$

6.2 The Solution of PVC Model

Through the establishment of the above model, we perform the operation to obtain the following image:

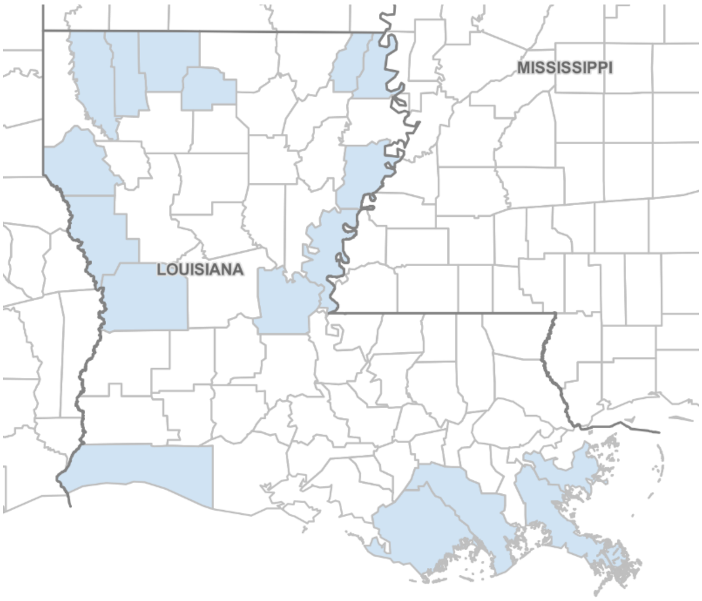


Figure 16: Map of suitable areas for construction in Louisiana

The return value of the regions marked in blue on the map under the arcgis spatial modeling model is better than that of other regions, which indicates that the data of various evaluation indicators are better, so we say that these regions are suitable for construction and development.

7 Landmark Value Appraisal Model (LVA Model)

7.1 The Establishment of LVA Model

7.1.1 Determine Evaluation Index

In this section, we comprehensively consider the factors that need to be considered in the construction and development of a certain area, and choose four aspects of **history, culture, economy** and **community** as first-level indicators.

After reviewing a lot of literature, we counted a total of 36 official related indicators, and finally selected 12 of them as the secondary indicators of our evaluation model. The specific description and selected indicators are shown in Table 6.

Table 6: Selection and description of evaluation index

Primary index	Secondary index	Description
History	History length	The age of the building
	Impact of historical events	Places where major historical events took place
Cultural	Sense of culture admitting	Sense of regional identity of a local population
	Value of academic education	Demonstration in the field of education
Society	Social influence	Social popularity and appeal
	Unique regional style	Show community life style and spirit
Economics	Value of tourism development	Direct benefits (tickets, catering, hotels)
	Income level	The income of local residents

- Historical impact(H)
  1. Long history

Historical cultural heritage provides us with direct evidence of past social, cultural and technological development, is an important symbol of the continuity of human history, and is the irreplaceable value of cultural heritage.

  2. Influence of historical events

Cultural heritage related to major historical events can help us understand the process of change in the past, and such cultural heritage has a high educational value, providing rich materials for academic research.

- Cultural influence(C)
  1. Cultural identity

Cultural heritage is a vehicle for the shared memory of local populations, helping to build a sense of identity based on shared historical and cultural traditions, and thus promoting intergenerational connections and understanding

  2. Value of academic education

Cultural heritage provides a unique physical learning resource for academic education, providing students with direct access to historical sources and original forms of cultural expression, while also enabling students and researchers to develop critical and innovative abilities, which are essential for collaborative exchanges between subject areas

- Economic impact(E)
  1. Tourism development value

Cultural heritage with significant tourist attraction can promote tourism and bring direct and indirect economic benefits to the local area, including tourism consumption, job creation and increased government tax revenue

2. Income level (GDP)

The contribution of cultural heritage to GDP is a direct indicator of its economic value, which contributes to economic growth through revenue from tourism and related industries

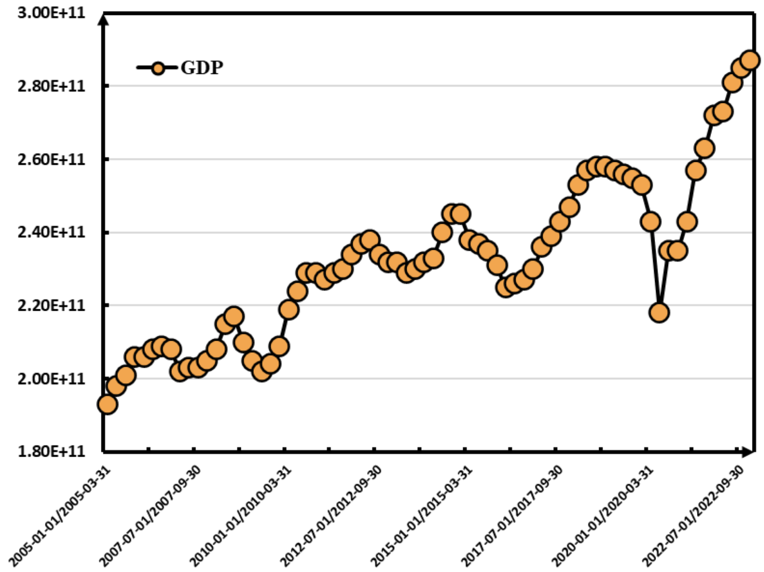


Figure 17: The trend of Louisiana's GDP

The above image shows the trend of Louisiana's GDP over the past 20 years, and its growth trend is inseparable from the promotion of landmark.

- Social impact(S)

1. Social influence

Cultural heritage with significant social impact plays a key role in promoting cultural transmission and has had a profound impact on social customs, law, art or science.

2. Unique regional style

The cultural heritage with a unique regional style enhances the visibility and attractiveness of the region at home and abroad, helps to promote cultural tourism and economic development, and at the same time, the unique regional style also demonstrates the cultural diversity of the local area.

7.1.2 Weight Calculation

In the process of calculating the weight, we use Topsis model based on entropy weight method.[8]

Establishment of decision matrix(M): The performance data of land construction and development plan relative to four evaluation indexes of history, economy, culture and community were collected.

Construct decision matrix

$$X = [x_{ij}]$$

Where $i=1,2,\cdots n$ represents the number of schemes, $j=1,2,\cdots n$ represents the number of evaluation indicators, x_{ij} is the performance value of the i scheme under the j index

1. **Normalize the Decision Matrix (R):** Transform raw data to a common scale to neutralize unit differences, ensuring comparability.

$$r_{ij}=\frac{x_{ij}}{\sqrt{\sum_{i=1}^{n}x_{ij}^{2}}} \tag{17}$$

2. **Calculate the Proportion (P):** Determine the share of each criterion in the total, highlighting its relative significance.

$$P_{ij}=\frac{r_{ij}}{\sum_{i=1}^{n}r_{ij}} \tag{18}$$

3. **Calculate Entropy(E):** Measure the disorder or diversity of information provided by each criterion; lower entropy indicates more valuable information

$$e_{j}=-k\sum_{i=1}^{n}p_{ij}\log\left(p_{ij}\right) \tag{19}$$

Where $k=\frac{1}{\log(n)}$.

4. **Calculate Divergence (D):** Reflect the importance of criteria based on their entropy; less entropy means higher divergence and importance

$$d_{j}=1-e_{j} \tag{20}$$

5. **Calculate Weights (w):** Assign weights to criteria based on their divergence, indicating their relative importance in the analysis.

$$w_{j}=\frac{d_{j}}{\sum_{j=1}^{m}d_{j}} \tag{21}$$

7.1.3 Establishment of Protection Scheme

The protection measures of cultural heritage are multifaceted, aiming to ensure the long-term preservation and inheritance of cultural heritage. Through consulting a large number of literatures, we summarized three common protection measures, as shown in the figure 18.

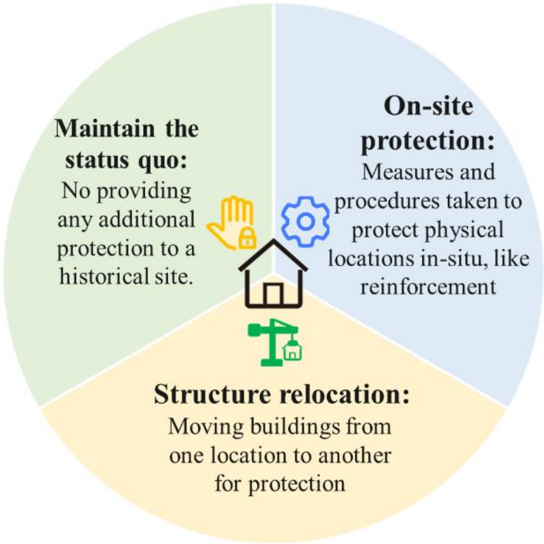


Figure 18: Demonstration of three protective measures

Obviously, when different protection measures are taken, their evaluation indicators will be affected, and thus their value will be affected, so we should consider the consequences of each protection measure in advance when considering which protection measure to choose. To quantify this impact, we can construct a simplified model that assesses the contribution of different conservation measures to the value of cultural heritage by introducing coefficients.

- **Define the dimensions of landmark value:** Above, we have defined the four dimensions of social value (V_S), history value (V_H), economy value (V_E) and culture value (V_C).
- **Determined protection factor:** For each conservation measure(M_i), a coefficient(C_i) is defined to indicate the degree to which the measure contributes to each value dimension of the cultural heritage. This coefficient can be based on expert evaluation or analysis of historical data, and usually ranges from 0 to 1.
- **Construct evaluation formula:** Using these coefficients, we can construct an evaluation formula to calculate the comprehensive value of cultural heritage.

$$V = \alpha(V_H \times C_H) + \beta(V_S \times C_S) + \gamma(V_C \times C_C) + \delta(V_E \times C_E) \tag{22}$$

Where α、β、γ、δ is a weight coefficient, selected according to the characteristics of cultural heritage and conservation objectives

According to different protection measures, we have consulted a large amount of literature to explore their impact on landmark value, which is divided into four levels:

Positive low: Indicates that the measures can bring a slight improvement, although the change is not large, but still contribute to maintaining or slightly improving the state of the building.

Positive high: It indicates that the protection measures directly lead to a significant positive development of the indicators, and this change has a decisive role in the protection, function improvement or value increase of the landmark.

Negative low: It does not cause significant damage overall, but still requires concern and can be mitigated by taking remedial measures

Negative high: The representation measures bring about significant negative changes that may have a significant adverse effect on the conservation, value or function of the building.

Taking into account the impact of different protection measures, we rated multiple evaluation indicators in four aspects that have been identified, the results are as follows:

Table 7: The impact of conservation measures on evaluation indicators[9]

Historical value index[10]		
Long history	**Negative low**	It affects people's perception of the historical depth of the landmark
Impact of historical events	**Negative high**	It may reduce its intuitiveness and persuasiveness as a historical witness
Cultural value index		
Sense of culture admitting	**Negative low**	The weakening of ties can lead to cultural fault lines
Value of academic education	**Positive low**	A move to more accessible locations would be more accessible to and academia
Economic value index		
Value of tourism development	**Positive high**	Relocation will make landmarks more accessible to the public a
Income level	**Positive low**	Stimulate economic growth and create jobs
Community value index		
Social influence	**Positive low**	Promote communication between different cultures
Unique regional style	**Negative high**	Difficulty in conveying cultural meaning in a new environment

7.2 The Solution of LVA Model

In this section, the landmark we selected is the World War II Museum, and we need to get its score to judge its conservation measures.

Figure 19: Photos from the World War II Museum

In order to unify the measurement standards, we found a total of ten landmarks, including two landmarks that have been relocated, namely Hamilton Grange and Cook's Cottage, and tested their indicators as data sets and took their scores as evaluation criteria. The running results are as follows.

Table 8: Landmarks rank and score

	Index	Sorted_S
National War II Museum	**2**	**0.1814**
Cook's Cottage	**1**	**0.2936**
Hamilton Grange	**3**	**0.1465**
Cape Hatteras	**4**	**0.0989**
The Statue of Liberty	**6**	**0.0890**
Hamilton Grange	**7**	**0.0517**
Jamestown	**8**	**0.0443**
Quirigua Ruins	**5**	**0.0947**

It is easy to see from Table 8 that the score of World War II Museum is 0.1814, which is between Cook's Cottage and Hamilton Grange. We also observed seven other sets of data, all of which are lower than these two landmarks, indicating that the model and evaluation criteria we established are reasonable, so we can propose relocation protection measures for World War II Museum.

Combining the insurance model and the value model, we finally recommend the relocation of the World War II Museum to Metairie, the demolition cost is estimated to be around \$20 million to \$50 million, the transportation cost is estimated to be\$21 million to \$11.5 million, and the reconstruction cost is estimated to be between \$50-100 million.

8 Sensitivity Analysis

Climate risk Value (CVaR) and Landmark Value Appraisal Model (LVA Model) are our basic model, so we perform sensitivity analysis on the parameters of this model.

We changed the ICR in the CVaR model to a range of 0.1 up and down from 0.9 as the reference point, and the error of CVaR is shown in the figure 20, obviously, the error percentage is within the range of $\pm 5\%$, which is in line with the expected accuracy of the model. So, it passed sensitivity analysis.

Next ,we changed the α in the LVA model to 05 is the range of 0.1 up and down the reference point, and the error of V is shown in the figure 21, obviously, the error percentage is within the range of $\pm 3\%$, which is in line with the expected accuracy of the model.

The data show that despite the slight asymmetry, the model exhibits a high degree of stability and an error control within an acceptable range, reflecting the good reliability of the model. The sensitivity analysis results support our model as a robust and reliable tool to predict CVaR. Our models provide an accurate risk assessment within a reasonable range of changes in insurance coverage.

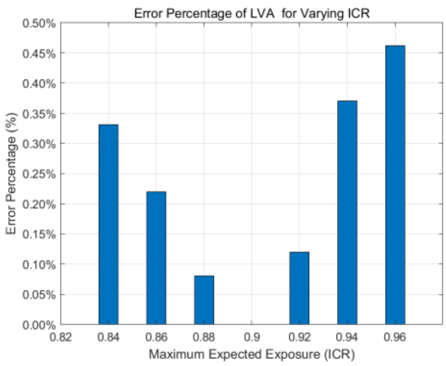


Figure 20: Error percentage of CVaR

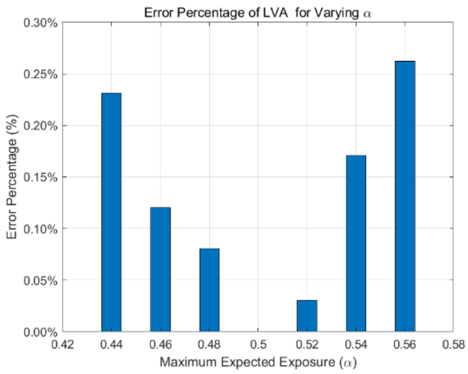


Figure 21: Error percentage of V

9 Model Evaluation and Further Discussion

9.1 Strength

Risk assessment framework: we provide a structured approach to assessing the potential risks associated with the phenomenon studied, making a significant contribution to the field. The framework covers a wide range of risk factors and provides a comprehensive picture of possible outcomes. It cleverly links theoretical structures with practical applications, facilitating the identification, quantification, and mitigation of risks. The versatility and depth of the framework ensures that it can be customized for different contexts, enhancing its usefulness and relevance in various fields.

Data forecast: We incorporate the strengths of the grey prediction and ARIMA models into the strengths of the problem Because GP's efficiency with limited data and ARIMA's ability for detailed time series analysis together enhance the analytical accuracy of the paper and broaden its applicability in different research and real-world Settings.

Robustness: Sensitivity analysis allows me to identify and quantify the impact of variable fluctuations on risk assessment, property valuation, and estate preservation strategies. By understanding these relationships, we are able to gain insight into how policies and strategies can be dynamically adjusted to better manage the uncertainties associated with natural disasters, thereby improving the adaptability and accuracy of our forecasting models.

9.2 Weakness

Data dependency: The performance of the model is highly dependent on the quality and availability of the input data. In cases where data is sparse or of low quality, the reliability and accuracy of the model may be compromised.

9.3 Future discussion:

We recommend examining policy implications and global-local dynamics in order to adapt strategies to changing circumstances. Emphasizing sustainability and resilience, we recommend looking into sustainable practices and resilience measures. In addition, ethical and societal considerations around the prioritization of fair insurance access and protection are highlighted.

10 Conclusion

To sum up, we first set up a Risk Prediction model, using grey prediction to calculate the probability of various natural disasters in the next year, and then give the calculation formula of insurance cost and insurance loss. Then we define the climate risk value (CVaR) and formally establish the Value at Risk model. When demonstrating our RPE model, we choose Louisiana and Sydney.

Aiming at the problem of "where to build and develop", we develop PVC Model. With the factor CVaR of the RPE model, we can assess the level of risk at a given location. We choose five parishes in Louisiana to show six factors.

Protection policies can be effective, such as reinforcing or relocation. For Landmark Value Appraisal Model, there are four primary indicators: history, cultural, society and economics. After calculating weights, we use ten landmarks to unify the measurement standard, finally recommend the relocation of the World War II Museum to Metairie.

The study makes a valuable contribution to "guiding insurance companies on whether to take on policies for areas with extreme weather" and "assessing whether buildings are landmarks" and encourages further investigation.

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The journey to preserve landmark

——A letter of advice to the community regarding the preservation of World War II museum landmark

Dear Community leaders and residents,

Our team is writing this letter out of deep concern for a valuable landmark in our community. Landmarks are not only an important part of our cultural heritage, but they tell the story of our community. However, with the increasing frequency of natural disasters, these priceless treasures are facing unprecedented risks. In view of this phenomenon, we set up an insurance model and a value model, and provide you with some suggestions and schemes according to this model.

Future plans

- **Communication with Local Governments**
- **Site Selection Considerations:**
- **Community Engagement**
- **Environmental Protection and Sustainability**
- **Project Implementation Plan**

Cost proposal

- **$20 million to $50 million**
- **$21 million to $11.5 million**
- **$50 million to $100 million**

Timetable

1 Disassembly phase

1-3 months

a. **Demolition building**

b. **Material handling**

2 Preparatory phase

2-6 months

a. **Material transportation**

b. **Design approval**

3 Construction phase

1-2 years

Construction

We believe that through the joint efforts of governments, communities and the public, we can effectively protect and pass on our cultural heritage. We look forward to your positive response and support, and are willing to provide more information and suggestions to jointly promote the progress of cultural heritage protection.

Our Team

2024.2.6