

## Indomitable In The Face Of Disaster

*Anyway, we will carry our own disasters. Go ahead without turning back.*

—Percy bysshe shelley

### Summary

The relationship between nature and human society has become a hotly discussed topic. Insurance industry, community, property developers have all faced with tricky problems when making decision. To help them solve the problem, we are expected to accomplish 4 tasks: 1. develop a model for insurance company to help them decide whether underwrite policy in an area; 2. help community and property developer with their building plan; 3. build a model to evaluate a building's value; 4. apply our model to a specific landmark.

To solve these problems, several models are built: **Model 1 HEV model for insurance company; Model 2 decision model for property developers; Model 3 protection model for community.**

**For task 1**, to develop a model for insurance company in section 4, we first established a natural disaster evaluation HEV model, which take different indicators into account, including **hazard, exposure and vulnerability**. Based on the HEV model, we can figure out the risk aversion coefficient. The Mean-Variance Premium Principle is used to determine the level of property and casualty insurance expenditures in an area, which is then combined with the HEV model to determine if an area is suitable for insurance.

**For task 2**, to help community and property developer with their building plan, we establish a model to rate different area in section 5. We first collect data of various indicators and use **entropy-method** to weight the indicators. Combined with the HEV coefficient, we build a ranking system, which will provide us with the score of different areas. Community can choose the area with the highest score to build the property. Also, the model will tell the property developer about the information of how to build.

**For task 3**, we use **entropy-method** and **TOPSIS method** to determine whether to protect a building and the preservation extent. We first collect various indicators and calculate the weight to create a decision matrix. Then we use TOPSIS calculate the relative proximity from ideal solution, which help us rank different building. The building that get the highest rank is the one we need to put into the most investment.

**For task 4**, we choose Confucius Hall in Hainan Province, China to apply our model. We model in section 6 to analyze the building's characteristic, which provide us with the insight in preservation. After that, we come up with a preservation suggestion.

Finally, we make assessment about our model in section 7, which deepen our insight in the strength and weakness of our model.

Our team use the AI tool Chatgpt in solving this problem, primarily to retrieve areas that frequently experience extreme weather events as well as historical landmark, as well as to aid in our initial understanding of unfamiliar models.

**Keywords:** Insurance Decision, Property Development Building Preservation, HEV, entropy-method, TOPSIS

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# 1 Introduction

## 1.1 Background

As global warming increases and the climate system becomes more volatile, more and more extreme weather disasters are occurring around the world, causing significant losses for property owners, communities, and insurance companies. The world has endured “more than 1 trillion dollar in damages from more than 1,000 extreme-weather events in recent years.” Based on the frequent occurrence of weather disasters, many insurance companies and communities have responded with initiatives. However, due to the lack of the current assessment system, it is still impossible to completely eliminate the impact of weather disasters on the above subjects. Therefore, it is necessary to build a model to reflect the risk of weather hazards and make recommendations for real estate owners and community owners.

## 1.2 Restatement of the Problem

Despite many in-depth analyses and research in extreme weather events and its relevant problems, a well-established model to evaluate extreme weather events is necessary, as well as a decision model for real-estate owners, community and insurance company. To handle these problems, the following tasks are expected to accomplish.

- **Task 1:** Develop a model for insurers to determine whether they should underwrite in areas where extreme weather events are on the rise. And use statistics in two areas which are on different continents and are experiencing extreme weather to demonstrate the model.
- **Task 2:** Build a model to help communities and property developers decide where, how, and whether to build on certain sites and make appropriate future real-estate decisions.
- **Task 3:** Build a preservation model to help community leaders determine the extent of measures they should take to preserve buildings with cultural or community significance in their community.
- **Task 4:** Apply our insurance and preservation models to assess the value of a specific landmark. Compose a one-page letter to the community recommending a plan, timeline, and cost proposal for the future of their treasured landmark.

## 1.3 Our Work

Firstly, we collect data of indicators of hazard, vulnerability, exposure. By mean variance premium principle and building HEV model, we find out Area's premium pricing principles and risk factors, scoring. Then we use our result to make suggestions for insurance company.

Secondly, we collect data of indicators of external environment. Using entropy-method, we find out property building scoring. Combined with HEV risk scoring, we build up property developer decision making model and make suggestions for them,

Lastly, we collect data of indicators of building characteristic. With entropy-method and TOPSIS, we get the scoring of historical building. Then we build a model for

community to help them decide whether to protect a building and so on. At the end we apply our model to a specific building and make assessment.

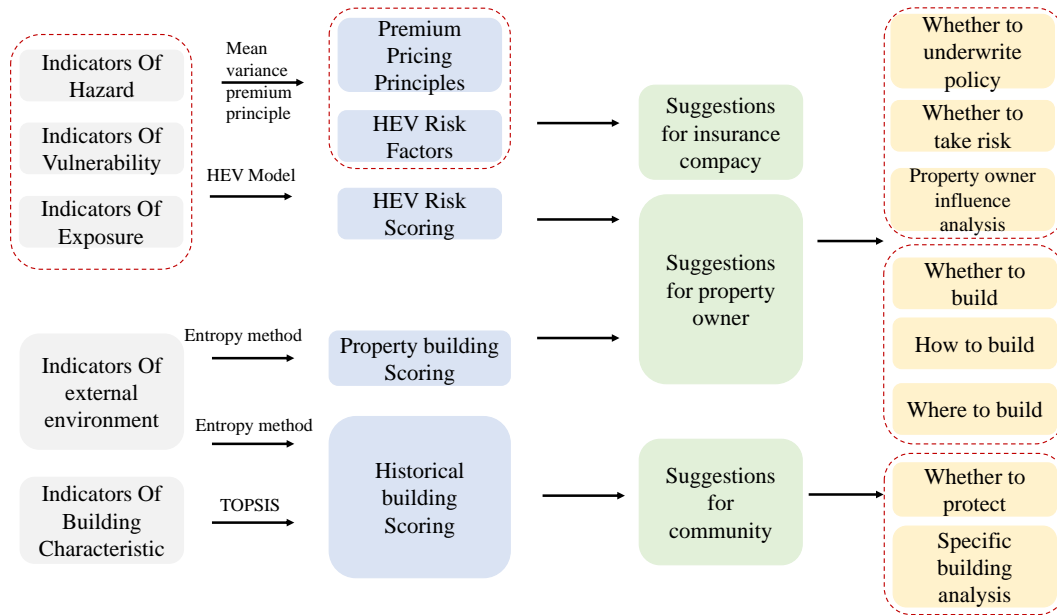


Figure 1: Our work (From Team # 2418813)

## 2 Assumptions and Explanations

**Assumption 1:** Extreme weather events are cyclical in nature.

**Explanation:** Our model predicts the likelihood of disasters and hazards through natural indices. Therefore, it is assumed that disasters occur with a certain periodicity.

**Assumption 2:** Meteorological conditions were broadly similar in different years in the same area.

**Explanation:** For simplicity of calculation, we assume that the meteorological conditions in the same area are the same in different years. For example, the average annual relative humidity, the average monthly temperature difference, and the number of days with different wind speeds.

**Assumption 3:** The state of the environment in a region can be accurately measured by different specific indicators.

**Explanation:** For example, the historic value of a building can be accurately measured by three indicators: the age of the building, the level of historic heritage designation, and the amount of money invested annually in the preservation of the building.

**Assumption 4:** Our indicators conform to a normal distribution.

**Explanation:** To assign weights to the indicators we use the entropy weighting method. The entropy weighting method needs to conform to a normal distribution as much as possible.

Additional assumptions are made to simplify analysis for individual sections. These

assumptions will be discussed at the appropriate locations.

### 3 Model Preparation

#### 3.1 Notations

Some important mathematical notations used in this paper are listed in Table 2.

Table 1: Notations used in this paper

Symbol	Description
$H$	Hazard
$V$	Vulnerability
$E$	Exposure

#### 3.2 Data Collecting And Cleaning

##### 3.2.1 Data Collection

Data are mainly collected from the World Weather website, China Meteorological Administration (CMA) and official website of the Insurance Industry Association.

Table 2: Data Source

Database	Website
World Weather Website	<a href="https://www.weather.gov/">https://www.weather.gov/</a>
CMA	<a href="https://weather.cma.cn/">https://weather.cma.cn/</a>
Insurance Industry Association	<a href="https://www.iachina.cn/">https://www.iachina.cn/</a>

The data sources are summarized in Table 2. We extracted the data that are completed in the past ten years and valuable to reflect the state of the Insurance Industry, Extreme Weather Conditions, and state of Historic Buildings.

##### 3.2.2 Data Pre-processing

- **Data Filling**

Due to our lack of access and sufficient access to resources and data pathways, the data we collect is missing and may not be entirely accurate. We have adopted the following methods to make the data more analyzable and valuable:

1. If a region had fewer years of missing data for an indicator and the variance of that indicator was relatively small, we filled in the average of the other years for that region.
2. If a region has fewer years of missing data for an indicator and the correlation of the indicator with other regions is relatively strong, we fill in the missing values using averages from other regions that are similar to it in terms of distance or otherwise.

3. the correlation between the indicator and the year indicator is relatively strong, we would use regression interpolation.

- **Dealing with outliers**

After collecting data, we analyzed each indicator. We eliminated outliers in each indicator that could compromise accuracy and validity. We filled in the averages between two similar metrics.

## 4 Underwrite Policy Decision Model For Insurance Company

In order to help insurers to determine whether they should underwrite in areas where extreme weather events are on the rise, we firstly develop the RISK model for rating disaster risk degree in different areas.

### 4.1 Indicators Of HVE Model

The HVE model is a qualitative way to calculate disaster risk degree in different area: H is Hazard, which indicates the level of natural hazard risk, related to the intensity and frequency of disasters; V is Vulnerability, which indicates the vulnerability of the bearer, related to the degree of preparedness of the bearer to cope with the disaster, related to the degree of preparedness of the bearer to cope with the disaster; E is Exposure, which is related to the object and degree of potential exposure to external hazards. [1] The model is expected to be comprehensive and considers different aspects of a specific disaster. Thus, we considered four different disasters: floods, typhoons, fires. We will demonstrate our result by making use of the statistics from two different areas. Meanwhile, HVE model calculations are different for different meteorological hazards, which we'll explain more detailed information in sectors 4.2.

### 4.2 HVE Level For Risk Evaluation

#### 4.2.1 The Calculation Of Hazard

Due to the different impact factors of different hazards, the methods used for different hazards have different scales for calculating H.

##### 1. Hazard Of Flood

- **Indicator**

**Frequency of rainfall from different level:** Because flooding is closely related to heavy rainfall[2], H for flooding is expressed as the weighted frequency of heavy rainfall and rainfall above the intensity of heavy rainfall.

- **Calculation**

$$H_{flood} = \frac{0.5 \times P_{1i} + P_{2i} + 1.25 \times P_{3i}}{\sum_{i=1}^n (0.5 \times P_{1i}) + \sum_{i=1}^n P_{2i} + \sum_{i=1}^n (1.25 \times P_{3i})} \quad (1)$$

$P_{1i}$  is the frequency of 24-hour precipitation between 50 and 99.9 mln in year  $i$ .

$P_{2i}$  is the frequency of 24-hour precipitation between 100 and 249.9 mln in year  $i$ .

$P_{3i}$  is the frequency of 24-hour precipitation greater than 250 mln in year  $i$ .

## 2. Hazard of Typhoon

### • Indicator

**Frequency of winds of different intensities:** There are three disaster-causing factors of typhoons, which are high winds, heavy rainfall, and storm surge[3]. Therefore, we firstly divide these three disaster-causing factors into internal intensity levels, and then find the frequency of occurrence according to the results of the division respectively, and finally weight and sum the frequency to get the typhoon's H level.

### • Calculation

$$H_{typhoon} = \sum_{i=1}^n W_i \times N_i (i = 1, 2, \dots, n) \quad (2)$$

$N_i$  is the frequency and  $w$  is the weight of different levels of disaster. We weight and sum the intensity of typhoon gales, windstorms and storm surges, where  $w$  is the weight of each hazard, derived from past data, and  $N_i$  is the frequency with which the hazard occurs.

The weights of the three disaster-causing factors were mainly calculated using Analytic Hierarchy Process(AHP) based on the importance ranking of the contribution of typhoon winds, rainstorms and storm surges to the typhoon disaster in coastal areas and the construction of a judgment matrix.

## 3. Hazard Of Forest Fire

### • Indicator

1. **Relative humidity:** If the air humidity is low and the saturation difference is high, combustible materials within the forest tend to dry out and increase combustibility.

2. **Evaporation:** The greater the evaporation of water, the drier the combustible materials within the forest, especially the coarse combustible materials with significantly lower water content, the more likely to occur in large forest fires.

3. **Precipitation:** the size of precipitation directly affects the water content of combustible materials in forest areas. If the annual precipitation of an area exceeds 1500 millimeters, or the monthly precipitation exceeds 100 millimeters, forest fires generally do not occur or occur less often.

4. **Temperature difference:** As the temperature rises, the saturated water vapor pressure of the air increases, the relative humidity decreases, the water content of the combustible materials on the ground surface, especially the fine dead combustible materials, decreases, and the risk of forest fire rises.[4]

### • Calculation

$$H_{fire} = w_1 \times RH + w_2 \times Eva + w_3 \times R + w_4 \times \Delta T \quad (3)$$

$RH$  is Relative humidity.

$Eva$  is Evaporation.

$R$  is Precipitation.

$\Delta T$  is Temperature difference.

#### 4.2.2 The Calculation Of Vulnerability

Since all disaster-affected bodies possess demographic, economic, and social elements, we use a consistent evaluation approach to indicate vulnerability in different regions for different disasters.

- **Indicators**

1. **population intensity**

The higher the population density, the greater the number of people who may be harmed in the area where the natural disaster occurs

2. **GDP**

GDP represents the sum of all final goods produced in a region. the higher the GDP, the higher the economic losses in the event of a severe meteorological disaster.

3. **urban population share**

The higher the urban population share, the greater the number of people affected in the city

4. **the share of the primary sector in the GDP**

The primary industry refers to agriculture, forestry, animal husbandry and fishery, which is the most basic source of means of subsistence for human society. The primary industry is characterized by the direct use of natural resources, providing human society with basic means of life and survival, which is basic and irreplaceable. Therefore, the greater the share of the primary sector in the GDP, the slower the recovery of the city's economy and other aspects when hit by natural disasters.

5. **GDP per capita**

GDP per capita represents the material standard of living. The higher the GDP per capita, the greater the likelihood that people's property will be affected.

- **Calculation**

$$V = \sum_{i=1}^n W_i \times D_i (i = 1, 2, \dots, n) \quad (4)$$

$W_i$  refers to the weight of indicator  $i$ , and  $D_i$  refers to the standardized value of indicator  $i$  of different city. More detail are shown as following:

#### 4.2.3 The Calculation Of Exposure

Exposure analysis is an assessment of the population or property that is exposed to the effects of natural hazards. Therefore, first we need to determine and categorize the hazard-affected body in the study area, and then count the number of hazard-affected bodies exposed to the hazard. Since the direct hazard-affected bodies are different between forests and populated areas, the calculation method of our exposure model is different, as follows:

- **Forest Fire**



Table 3: Standardized values of vulnerability indicators for disaster affected body

Standardized Value	A	B	C	D	E
1	$<225$	$<250$	$<0.26$	$<5.4$	$\geq 3.80$
2	$225 \leq X < 415$	$250 \leq X < 645$	$0.26 \leq X < 0.32$	$5.4 \leq X < 9.6$	$2.15 \leq X < 3.80$
3	$415 \leq X < 555$	$645 \leq X < 1250$	$0.32 \leq X < 0.40$	$9.6 \leq X < 15.0$	$1.50 \leq X < 2.15$
4	$555 \leq X < 730$	$1250 \leq X < 2325$	$0.40 \leq X < 0.56$	$15.0 \leq X < 22.2$	$1.15 \leq X < 1.50$
5	$\geq 730$	$\geq 2325$	$\geq 0.56$	$\geq 22.2$	$\leq 1.15$

\*A is population intensity(person/km<sup>2</sup>), B is GDP(thousand yuan/km<sup>2</sup>), C is urban population share(%), D is the share of the primary sector in the GDP(%), E is GDP per capital(thousand yuan/person).

$$E_{fire} = S \times T \quad (5)$$

$S$  is the size of an area.  $T$  is the price of forest, including direct economic loss of trees, fire suppression costs per unit area, loss of other fixed assets per unit area.

- **Typhoon, Flood**

$$E = \rho \times P \quad (6)$$

$\rho$  is the regional housing density.  $P$  is the regional unit house price.

#### 4.2.4 The Calculation Of HVE Level

We use the result of Hazard, Vulnerability, Exposure to calculate the HVE Level  $a$ .

$$a = H \times V \times E \quad (7)$$

### 4.3 Mean-Variance Premium Principle

By reviewing the literature, we found that:

- Most natural disasters are cyclical and non-repeating, and for this question, the cycle is set at five years.
- The impact of natural disasters on a region can be approximated by the natural disasters in the city where it is located.
- Based on the selected city, floods, forest fires and typhoons are the main natural disasters, and the frequency of the remaining natural disasters is too low to be approximated.

Due to the cyclical nature of natural disasters, we believe that the number of insurance claims follows a gamma distribution.

To help insurance company determine whether to underwrite policy locally, we use the Mean-Variance Premium Principle.

The Mean-Variance Premium Principle is based on portfolio theory and takes into account the uncertainty of future claim amounts and considers the trade-off between risk and reward. Specifically, the mean-variance premium principle recognizes that

premiums should be equal to the expected value of future claim amounts plus a risk premium that is based on the variance (or standard deviation) of the claim amounts.

This principle takes into account not only the average expected value of claims, but also the volatility of claim amounts. This allows the insurer to determine a reasonable premium that covers the expected cost of the claim and compensates for the risk assumed. This approach is particularly suitable for insurance products where the level of risk is difficult to predict, or where the amount of claims is volatile.

The mathematical expression of the mean-variance premium principle is usually as follows.

We set  $X$  as random variable for future claim amounts, Its expectation is  $E[X]$ , variance is  $Var[X]$ . According to the mean-variance premium principle, premiums  $p$  can be expressed as:

$$P = E[X] + \alpha \cdot Var[X] \quad (8)$$

- $E[X]$  is the expected value of the amount of future claims and represents the average probable loss. It is determined by averaging the per capita premiums for each province (district, autonomous region) within a country.

- $Var[X]$  is the variance of future claim amounts, indicating the volatility or uncertainty of claim amounts. It is determined by the degree of dispersion of per capita premiums across provinces (regions, autonomous states) within a country.

- $\alpha$  is the risk aversion coefficient, which reflects an insurer's attitude towards risk. the larger the alpha, the more sensitive the insurer is to risk, and hence the higher the premium it will demand to compensate for taking on additional risk. The larger this coefficient is the higher the risk premium demanded, as determined by the insurer based on its own business situation. When  $\alpha = 0$ , the insurer exhibits a neutral attitude towards risk. Based on the *HEV* and mean-variance premium principles, we determine whether an area should be insured by the following two metrics:

- According to the normal distribution of risk  $N(\mu, \sigma^2)$  obtained from the previous fitting of the *HEV* model, we select the risk interval that can be insured within  $[0, \mu + \sigma]$ , at this point, there are about 16% of the area is recognized as a "high risk area", and then we also need to This will need to be further determined based on the local property and casualty insurance expenditures.

- When a region is recognized as a "higher disaster risk region", we then determine its local property and casualty insurance expenditure according to the mean-variance premium principle, according to the formula (the formula of the mean-variance premium principle), combined with the risk coefficient calculated by the specific insurance company  $\alpha$ , you can get the estimated value of local property and casualty insurance expenditure, and then compared with the local property and casualty insurance expenditure. Estimated value, and then compared with the actual local property and casualty expenditure, if the actual local property and casualty expenditure is greater than the estimated expenditure, then it is considered that this area is "high property and casualty expenditure area", then do not insure it.

Taking China as an example, the distribution of risk factors in China's provinces and regions was calculated, and the overall descriptive results obtained statistically for the country's 34 provinces for a five-year cycle of risk factor calculations are as follows:

Variable	sample size	median	mean	standard deviation	skewness	kurtosis
risk factor	34	0.53	0.55	0.15	-0.43	1.55

Figure 2: Indicators of Decision Model (From Team # 2418813)

It can be obtained that its kurtosis (1.545) absolute value is less than 10 and skewness (-0.431) absolute value is less than 3, which is further analyzed by combining the normal distribution histogram and Quantile Quantile Plot.

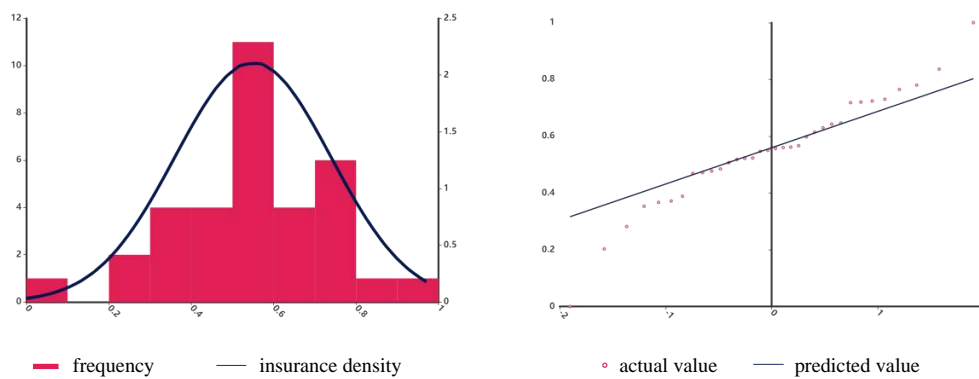


Figure 3: graph of HEV model risk factors (From Team # 2418813)

- As can be seen from the histogram of the normality test for the risk factor, the normality plot basically shows a bell shape (high in the middle and low at the ends), and the data, although not absolutely normal, can be initially accepted as normally distributed;

- As can be seen from the Q-Q plot, the distribution of the risk factor on the Q-Q plot basically conforms to being on a straight line, so it is basically acceptable as a normal distribution.

We have obtained the following overall descriptive results for the 31 provinces in the country for which statistics are available for the last five years of per capita property insurance expenditures:

Variable	sample size	median	mean	standard deviation	skewness	kurtosis
insurance density	31	730	845.81	387.19	2.25	5.10

Figure 4: Indicators of Decision Model (From Team # 2418813)

## 4.4 Two Areas Analysis

We have selected Hainan Province in China on the Asian-European continent and Brisbane in Australia on the Australian continent as example regions.

Taking Hainan Province as an example, the region is surrounded by the sea on all sides, located in the northern part of the South China Sea, which is the region where the typhoons in the northwest Pacific Ocean often pass through. It is in the tropical and subtropical climate, with high temperatures and high humidity where typhoon disasters often occur:

- Its actual risk factor  $R_c$  for 0.764, from the above table, calculated to insure the risk interval for  $[0.7]$ , at this time, the risk factor of Hainan Province  $R_c = 0.764 > \mu + \sigma$ , so that the region is recognized as a "higher risk disaster area", whether to carry out the Whether or not to insure requires the next step of judgment. - Since the establishment of risk aversion coefficient is more complex and specific, involving specific insurance companies on the market conditions, company strategy and the comprehensive assessment of customer risk appetite. We assume that an insurance company to maintain a neutral attitude towards risk, that is,  $\alpha = 0$ , at this time, the local property and casualty insurance expenditure is estimated to be the average value of 845.806, and the actual local property and casualty insurance expenditure of 902, which is greater than the estimated value, so it is recognized that the region is "higher risk areas".

As for Brisbane, the calculated risk interval is  $[0.732]$ , and the actual risk factor  $R_c$  is 0.584, which is considered to be insurable, so we recommend that the insurance company insure it.

## 4.5 Other Questions For Insurance Company

### 4.5.1 When should insurance company take the risk?

If an area always is hit by natural disaster, there is a good chance that an insurance company may lose money when underwriting in this area. However, an insurance company should take the risk of underwriting in this area when the following situations arise.

- **Regional development needs.** If a region is frequently hit by natural risks, the role of the insurance company is needed to regulate economic development. Otherwise, the local population is prone to suffer huge losses, and cannot compensate for the losses themselves. This will have a negative impact on social development and social stability.

- **Policy protection.** When the government provides policy protection for a disaster-prone area, the insurance company can take the risk. For example, the government cuts taxes and provides financial support.

- **Great potential for regional development.** If a region's economy is in a rapid development stage, and there are few competitors, the insurance company can take this risk to quickly capture the market and build a brand effect. After cultivating local residents into loyal customers, they can adjust the price of insurance to promote profitability.

#### 4.5.2 The Influence Generated By Property Owner

The key to an insurance company's profit and loss depends on the gap between the income and expenses of the insurance. The following will analyze how the property owner affects the income and expenses of the insurance company:

- **Income:** The main source of income for an insurance company is the premiums paid by the property owner. Revenue is related to the number and amount of insurance policies taken out by property owners. If most of the property owners in a region are risk averse and have increased their preparedness for catastrophic risks, then the number of insured policies increases. At the same time, if the property owner's expectation of the amount of loss increases, then their ability to afford the maximum amount of insurance sold will also increase. Insurance companies can thus increase premiums, which in turn increases revenue and profitability.

- **Expense:** The expenses of the insurance company mainly come from the amount of compensation for the property owner's loss when the risk actually occurs. If property owners take better precautions against risks, such as reinforcing their houses and using fire-resistant materials to build them, the houses will be more capable of coping with disasters such as typhoons, floods, and fires. In the event of these catastrophes, they become less likely to suffer losses, the insurance company's expenses become smaller, and profits increase.

## 5 Decision Model For Developers

It is significant for communities and property developers to invest resources to maximize the economic and social benefits of their projects. Choosing which area to start a real estate project in and how to build the real estate project are all issues that need to be considered. We will build a decision-making model to help property developers and community owners. In the model, we cover the macro-environmental indicators, consumption capacity indicators, development potential indicators, risk indicators and other aspects of the evaluation index system, and combine them with the  $p$  derived from the previous HEV model. Through these two models, we rate the real estate construction environment of a region.

### 5.1 Indicators of Decision Model

#### 1. Investment Risk

We present this indicator using supply and demand risk, purchasing power risk. The higher the investment risk, the more difficult it is to build a real estate project in the area.

#### 2. Macro-environment

The macroeconomic environment refers to the state and trend of the overall economy of a country or region. A stable macroeconomic environment increases demand and thus stimulates the property market.

#### 3. Development Potential

Refers to the potential capacity of a given area for future development. The devel-



Figure 5: Flow Chart of Decision Model (From Team # 2418813)

opment potential of an area may affect demand and prices in the real estate market.

#### 4. Consumption capacity

Consumption capacity refers to the income and wealth that an individual or household has at their disposal at a given time. It influences their purchasing power and choices in the property market.

We selected the 4 primary indicators above, and choose 10 secondary indicators, which are shown below. We have adopted all the indicators in our decision model.

LEVEL 1	LEVEL 2	DESCRIPTION	TYPE
Investment Risk (IR)	SD	<b>Supply and Demand Risk.</b> The potential imbalance between the availability of real estate properties (supply) and the demand from buyers or renters.	-
	PR	<b>Purchasing Power Risk.</b> The likelihood of changes in economic conditions affecting individuals' ability to afford real estate, impacting buying power.	-
Macro-environment (ME)	GD	<b>GDP.</b> The total monetary value of all goods and services produced within a country's borders in a specific time period.	+
	UL	<b>Urbanization Level.</b> The proportion of the population living in urban areas, reflecting the degree of urban development in a region.	+
Consumption Capacity (CC)	DI	<b>Disposable Income per capita.</b> The average income available for spending and saving per person after taxes and other deductions.	+
	HP	<b>Number Of Household Population.</b> The official count of residents within a particular administrative region.	+
Development Potential (DP)	SP	<b>Average Sales Price of Commercial Real Estate.</b> The mean price at which commercial housing units are sold in a given area.	+
	SA	<b>Sales Area of Commercial Real Estate.</b> The total floor area of commercial housing units sold, indicating the scale of real estate transactions.	-
	UA	<b>Usable Area per Capita.</b> The average space utilized per person, providing insights into living standards and spatial requirements.	-
	CA	<b>Construction Area of Commercial Real Estate.</b> The total floor area under construction for commercial housing projects, indicating development activity.	+
<b>Note</b> +: positive indicators, the more the better    -: negative indicators, the less the better			

Figure 6: Indicators of Decision Model (From Team # 2418813)

## 5.2 Weight Calculation

### step1 Data Processing

- **Negative Indicator Conversion**

$$x_{i,j} = maxx_{i,j} - x_{i,j} + minx_{i,j} \quad (9)$$

$x_{i,j}$  is negative indicator  $i$  of city  $j$ .

- **step 2. Variable Normalization**

$$y_{i,j} = \frac{x_{i,j}}{\sum_{i=1}^n x_{k,j}}, (1 \leq i \leq n, 1 \leq j \leq m) \quad (10)$$

**Step 2. Calculate the entropy value of the indicator**

For each indicator, we first calculate its weight in each region,[?]

$$p_{i,j} = \frac{y_{i,j}}{\sum_{k=1}^n y_{k,j}} \quad (11)$$

$P_{i,j}$  is the weight of the  $i$ -th region on the  $i$ -th indicator and is the normalized value.

The entropy value for each indicator is then calculated using the following formula:

$$E_j = -k \sum_{i=1}^n p_{i,j} \ln(p_{i,j}) \quad (12)$$

$$k = \frac{1}{\ln(n)} \quad (13)$$

$n$  is the number of cities. If  $p_{i,j} = 0$ , then define  $p_{i,j} \ln(p_{i,j}) = 0$ .

**Step 2. Calculate the weight** Firstly, we calculate the coefficient of variation of indicators:

$$G_j = 1 - E_j \quad (14)$$

then we can use  $G_j$  to calculate the weight of different indicators:

$$w_j = \frac{G_j}{\sum_{l=1}^m G_l} \quad (15)$$

$m$  is the number of indicators, i.e.10.

We have collected data from 19 cities in China to figure out the weight of different indicators, results as following.

LEVEL 1	LEVEL 2	WEIGHT
IR	SD	0.0169
	PR	0.0296
ME	GD	0.2727
	UL	0.0127
CC	DI	0.0128
	HP	0.1867
DP	SP	0.0357
	SA	0.3180
	UA	0.0189
	CA	0.0960

Figure 7: Weight Of Indicators Of Decision Model (From Team # 2418813)  
[6]

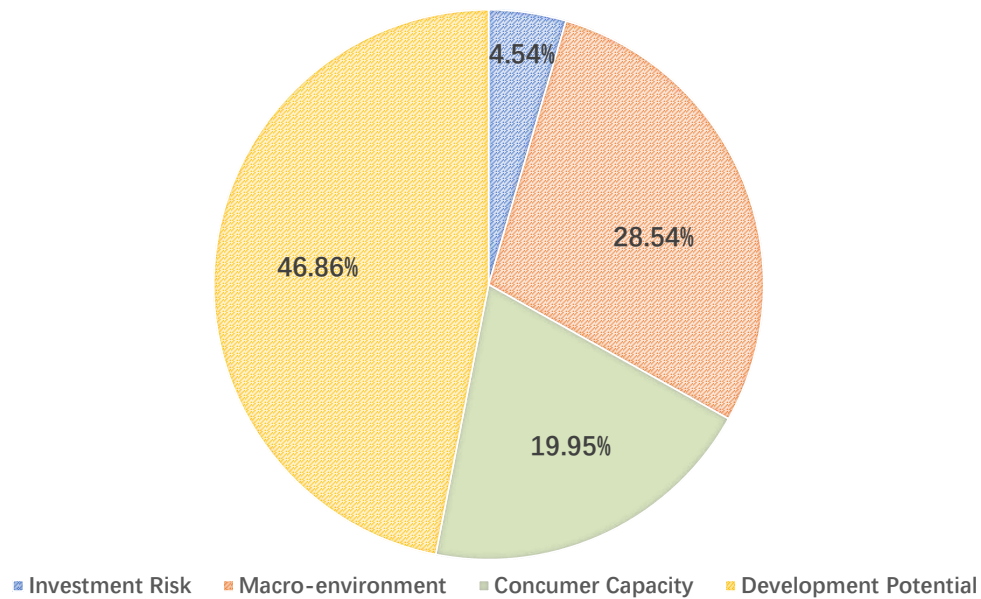


Figure 8: pie chart—Weight Of Indicators Of Decision Model (From Team # 2418813)

### 5.3 Rating Of Different Areas

In order to decide whether to build or not, we develop a rating system. Using HEV Model's score and the weight that have been calculate below, we can rate different areas and sort them by grades. More detailed process is shown below.

Firstly, we calculate the score of indicators apart from Hazard, Exposure, Vulnerability.

$$b_i = \sum_{j=1}^m w_j \times y_j \quad (16)$$



$b_i$  is the  $i^{th}$  city's score that rated by indicators apart from HEV.

Then we combine the score with HEV score together.

$$s_i = \left( \sum_{j=1}^m w_j \times y_j \right) \times a_i \quad (17)$$

$a_i$  is the HEV score,  $s_i$  is the total score of a city.

### 5.3.1 To build or not?

The higher the score, the higher the likelihood of development gained by building a property in this area. So we can use this scoring model in conjunction with the known area scores to estimate the potential for future development in this area. From the estimated development trends, the community and property owner can decide whether to build in this area or not.

### 5.3.2 How to build

When community and property developers decide to build, the next question is how to build. We believe that solving this problem requires first analyzing the values of our metrics after normalizing the weights assigned to them. Secondly, we need to identify the following principles for building houses. In order to be more specific, we take the area near the sea-viewing promenade in Xiashan District, Zhanjiang City, Guangdong Province, China, as an example for analysis. The index analysis chart is as follow.

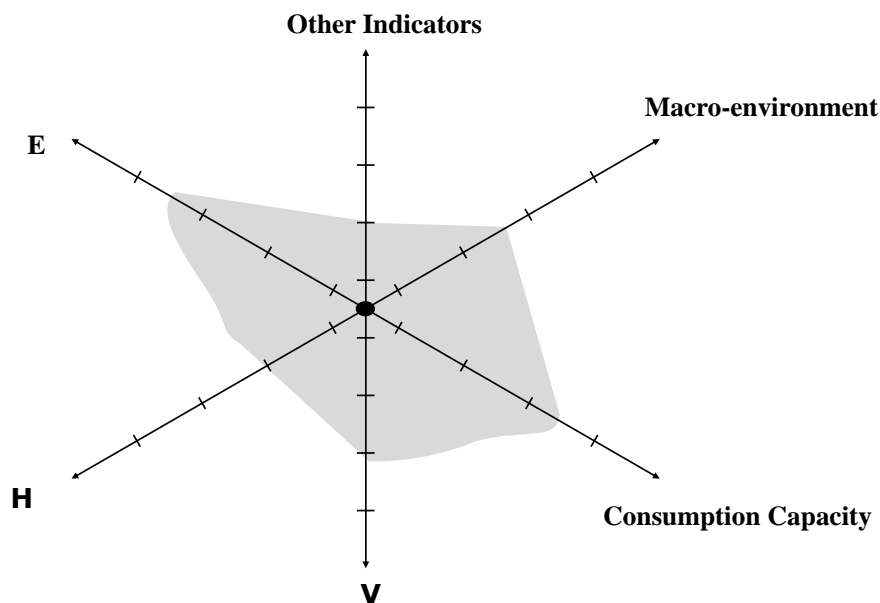


Figure 9: Indicators analysis of Zhanjiang (From Team # 2418813)

- **Principle Of Safety**

Due to the many factors involved in the real estate industry and the high investment risk, community and property developers need to pay more attention to making decisions on carrying out real estate projects. Before they make important decision,

they need to take necessary predictions on the risks that may arise, and make efforts to control them within a certain range. For example, typhoons occur frequently in Zhanjiang City, and both E and V are large, so sturdy materials should be used and windproof constructions should be selected when building houses.

- **Principle Of Economic Efficiency**

Under the principle of ensuring the safety of investment, community and property developers need to consider whether the project can continuously expand and gain profit. Take Zhanjiang City as an example, Zhanjiang City has high macroeconomic indicators and is judged to be in a rapid development stage. Due to the growing population, when building houses, we believe that the community should first consider building tall buildings in order to reduce the use of land area.

- **Principle Of Scientization And Democratization**

Community owners and property developers should consider the types of buildings that already exist in the area when building. The transportation system, medical system and other buildings should be distributed more evenly near each gathering point of residents to ensure basic supplies and services for the life of residents.

- **Systematic Principle**

The principle of systematicity requires that the project must comprehensively collect information related to the investment decision, such as land information, policy information, supply and demand information, market information, etc..

- **Timing Principle**

This is due to the prediction of the cycle of natural disasters. Taking Zhanjiang City as an example, since Zhanjiang is located in the southeast coast of China, the period from July to September always witnesses high incidence of typhoons. Key construction cycles of community and property developers should try to avoid this period.

## **6 Protection Model For Community**

### **6.1 Building Protection Model**

In this part, we mainly use entropy-weight method and TOPSIS Model to build the protection model, helping community make decision.

#### **6.1.1 Indicators Of Protection Model**

On the first part, we still select a series of indicators. The indicators are shown as below.

#### **6.1.2 Weight calculation—entropy-weight method**

Then we use entropy-weight method to determine different weight of indicators. This is done in the same way as the previous property building decision model.

We get the standardized data and weight of each indicator to develop a decision matrix.

LEVEL 1	LEVEL 2	DESCRIPTION	TYPE
Culture Value(CV)	CE	Cultural events. Number of cultural events (e.g., exhibitions, lectures, performances) in or associated with the building per year.	+
	NP	Number of people visiting the building per year.	+
	SI	Social media indicator. Number of mentions of the building on social media, including posts, hashtags, likes and shares	+
Historical Value (HV)	GA	The age of the building.	+
	HS	Historic status, i.e. the level of designation as a historic property.	+
	AI	The amount of annual investment used to maintain and preserve the historic character of the building.	+
Economic Value(EV)	AR	Total annual revenue generated by the building from tickets, event rentals, etc.	+
	JO	Job opportunity. Number of jobs created directly or indirectly by construction.	+
	AV	Asset value. Local land prices, market valuations or prices of the last transaction.	+
Community Value(CV)	CE	Number of community events. The annual number of community events (e.g., meetings, educational programs, community celebrations) held in the building.	+
	CS	Community Satisfaction. Community members' ratings of satisfaction and importance of the building.	+
	UA	Usable Area per Capita. The average space utilized per person, providing insights into living standards and spatial requirements.	+
	PL	Participation Level. The number of community members involved in building activities or services, or the number of hours community members volunteer for building maintenance and operations.	+
<b>Note</b> +: positive indicators, the more the better -: negative indicators, the less the better			

Figure 10: Indicators Of Protection Decision Model (From Team # 2418813)

$$V_{ij} = (v_{ij})_{m \times n} = (W_j v_{ij})_{m \times n} = \begin{pmatrix} W_1 v_{1,1} & W_2 v_{1,2} & \cdots & W_n v_{1,n} \\ W_1 v_{2,1} & W_2 v_{2,2} & \cdots & W_n v_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ W_1 v_{m,1} & W_2 v_{m,2} & \cdots & W_n v_{m,n} \end{pmatrix} \quad (18)$$

$w_j$  is the weight of the  $j^{th}$  indicator and  $v_{ij}$  is the standardized value of an indicator after weighted.

### 6.1.3 Ranking using TOPSIS

Next, we use the data above to determine the positive ideal solution ( $A^*$ ) and the negative ideal solution ( $A^-$ ). A positive ideal solution is a scheme consisting of the optimal values of each attribute, and a negative ideal solution is a scheme consisting of the worst values of each attribute. The details are as follows:

- For positive indicators:

$$\begin{cases} A_j^* = \max(v_{ij}) \\ A_j^- = \min(v_{ij}) \end{cases} \quad (19)$$

- For negative indicators:

$$\begin{cases} A_j^* = \min(v_{ij}) \\ A_j^- = \max(v_{ij}) \end{cases} \quad (20)$$

Then we calculate the standardized value  $v_{ij}$ 's distance between positive ideal solution and negative ideal solution.

- Distance from positive ideal solution:

$$D_i^+ = \sqrt{\sum_{j=1}^m (v_{ij} - A_j^*)^2} \quad (21)$$

- Distance from negative ideal solution:

$$D_i^- = \sqrt{\sum_{j=1}^m (v_{ij} - A_j^-)^2} \quad (22)$$

Finally, we calculate the relative proximity, which is

$$RC_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (23)$$

After we calculate the relative proximity, we can rank the score of different buildings. The greater the relative proximity, the closer the building's is to a positive ideal solution. At this point the building has a high metric score, indicating a high conservation value. This method can measure the degree of conservation necessity of the buildings in the community. The higher the building in the ranking, the more worthy it is of preservation. From there, community leaders can then subjectively determine which of the ranked buildings need to be preserved for policy and other reasons.

## 6.2 Historical Site Protection—Confucius Hall in Lingshui County

Confucius Hall is a historical landmark in Lingshui County, Wenchang City, Hainan Province, China, which is always hit by typhoons every summer from June to September. In order to compare the weather in Hainan with the weather in other cities in China, we have plotted the following graph. Since we do not have enough weather statistics for Wenchang, we use weather statistics for Haikou instead, since the distance is small enough to ignore weather differences.

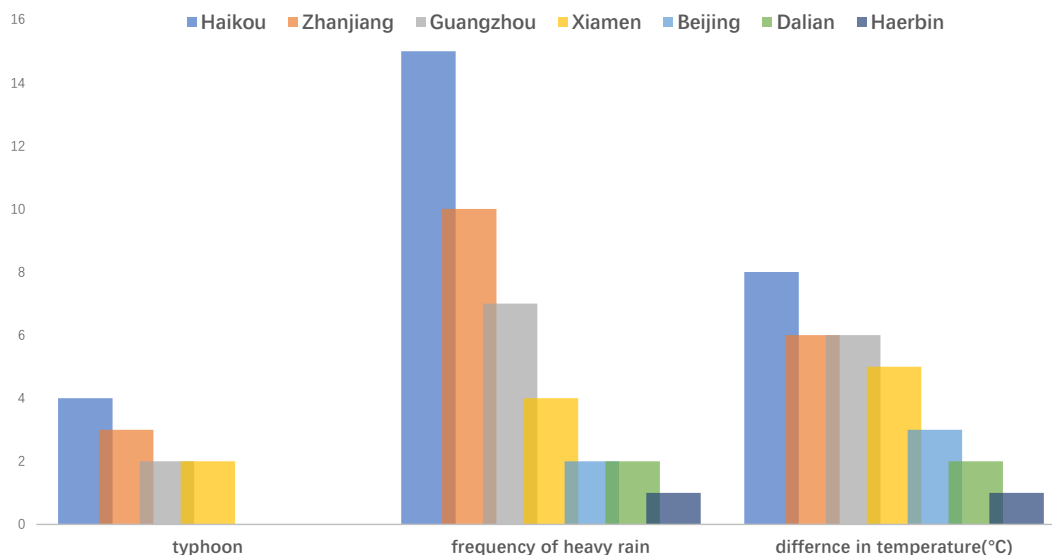


Figure 11: July's Weather in Hainan vs. other cities in China (From Team # 2418813)

Global typhoons occur mainly in eight sea areas. Of these, five are in the northern hemisphere, namely, the western and eastern parts of the North Pacific Ocean, the western part of the North Atlantic Ocean, the Bay of Bengal and the Arabian Sea, and three in the southern hemisphere, namely, the western part of the South Pacific Ocean,

the western part of the South Indian Ocean and the eastern part of the South Indian Ocean. Hainan is located in the western sea area of the South Pacific Ocean, belonging to the tropical monsoon climate zone, by the influence of the monsoon circulation, the rainy season and the early season is distinct. During the summer winds, because it is located in the low latitude of the ocean, precipitation by the typhoon influence is very large, the average annual direct landfall or impact of the province’s typhoon up to 8 or 9.

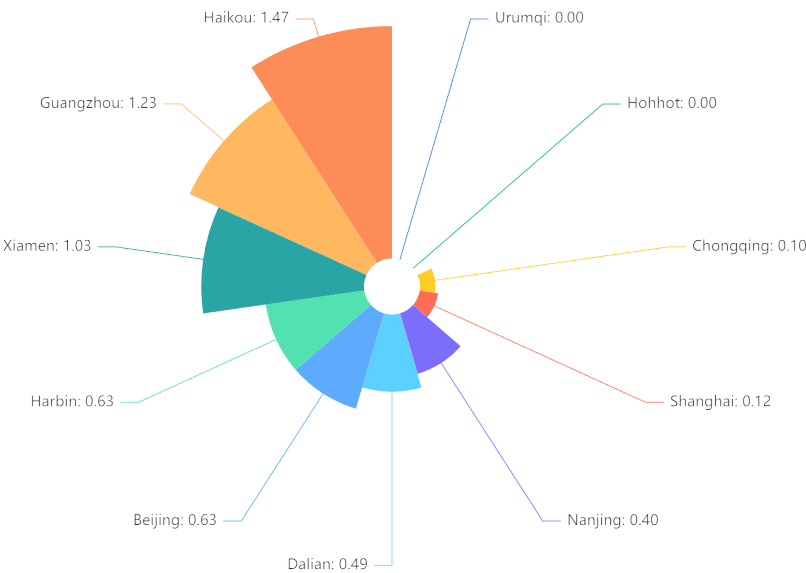


Figure 12: Indicators of typhoon in cities in China——From HEV Model (From Team # 2418813)

We applied our modeling to evaluate the value components of Confucius Hall as follows:

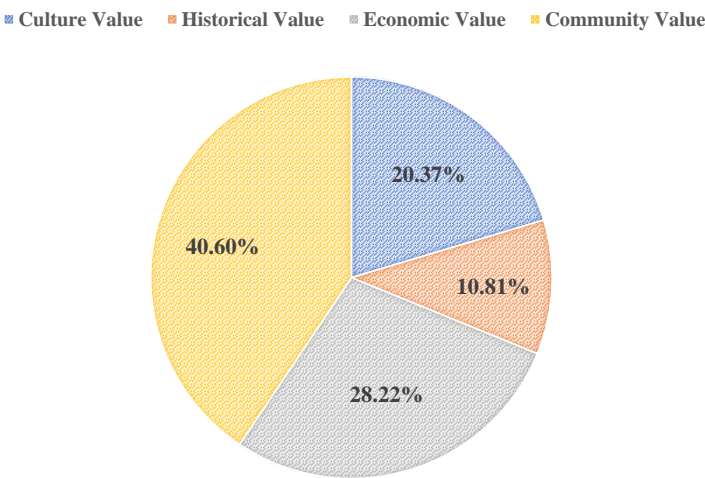


Figure 13: Value Assessment (From Team # 2418813)

We found that the largest proportions of value are community value and economic value, which means that this landmark has a great role in providing employment units

and promoting the economic growth of the community. At the same time, the landmark also has some historical and cultural significance. However, the structure of the building has been eroded by the typhoon. Therefore, immediate protective measures should be taken.

## **7 Evaluation Of The Models**

### **7.1 Strength**

1. We use HEV model from the disaster-causing factors and use entropy weighting method to calculate the weighting coefficient of flood, typhoon, forest fire. To a large extent, we reduce the interference of human factors, make up for the uncertainty of the field factors. The results show that with the actual disaster situation in line with the value of the weights is more reasonable, accuracy and credibility is high.

2. We apply the TOPSIS method to evaluate the program decision-making, and the rationality and scientificity of the evaluation method is of practical significance.

3. The overall decision-making judgment is based on the idea of information entropy, which can objectively reflect the difference and importance of different indicators. It can also reflect the calculation results are more accurate with stability and consistency, as well as the calculation formula is simple and easy to understand, with a wide range of application.

### **7.2 Weakness**

1. Fewer types of disasters considered. Age-old data are not easy to obtain, thus cannot accurately predict future disaster simulation. When using entropy weighting method to determine the weights, the default indicators as far as possible in line with the normal distribution, and the actual situation for the accuracy of the data, resulting in a slight deviation from the actual situation.

2. The use of TOPSIS method requires a large amount of data, and the quality of the data is relatively high, may not be able to take into account the subjective feelings and value judgment of people. Some non-quantitative indicators are difficult to use objective methods to find the weight. So we can not take into account the correlation between the indicators and adequately judge the impact of the number of indicators on the results.

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## A letter of Proposal

### for the Protection and Relocation of Confucius Hall in Lingshui County

Dear community owner,

I hope this letter finds you well. We are the Heritage Conservation Assessment Team, and following your commission for the conservation of cultural relics, we promptly applied our specialized model to assess Lingshui County in Hainan, China.

Hainan is frequently affected by extreme weather events. In recent years, the increased instability of the global meteorological system has led to a rise in typhoon frequency in Hainan. These climatic phenomena have adverse effects on the Confucius Academy in Lingshui, causing corrosion of its building materials in heavy rain and potential damage or displacement due to typhoons.

According to our model, Confucius Hall encompasses economic, cultural, social, and historical values, with economic and historical values holding the highest proportion. Due to the fact that it is a big building complex and can bring lots of economic and community value, we propose in-situ protection.

#### timeline

- February to March: Provision of security education to heritage protection staff, and implementation of 24-hour round-the-clock duty by security staff and night watchmen in forest areas March to April: Gather staff and plan transportation logistics based on the identified sections for relocation.
- April to June: Erecting a waterproof windbreak and coating the building with waterproof material .
- This proposed schedule ensures the smooth execution of preservation work, avoiding the months prone to typhoon disturbances.

#### Estimated costs:

- Personnel: \$5,000,000
- Waterproof material: \$30,000,000
- Miscellaneous funds: \$10,000,000

Total budget: \$45,000,000

We trust that this plan will ensure the successful preservation of the Confucius Academy. Please feel free to reach out if you have any further questions or require additional clarification.

Best regards,

Heritage Conservation Assessment Team





# Report on Use of AI

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1. OpenAI *ChatGPT* ((Nov 5, 2023 version, GPT-4)

**Query1: <What is the mean-variance premium principle?>**

Output:

<The Mean-Variance Premium Principle, also known as the Expected Value-Variance Premium Principle, is a method used in insurance and finance to calculate the premium of an insurance policy. According to this principle, the premium is determined not only based on the expected loss (mean or expected value) but also by incorporating the risk (variance) associated with the potential losses.

The formula for the Mean-Variance Premium Principle is generally expressed as:

$$[ \text{Premium} = \text{Expected Loss} + \alpha \times \text{Variance} ]$$

where:

- $(\text{Expected Loss})$  is the mean or expected value of the potential losses,
- $(\text{Variance})$  measures the variability or dispersion of the potential losses around their expected value,
- $(\alpha)$  is a risk-loading factor that reflects the insurer's risk aversion, the need to cover administrative costs, and the profit margin.

By considering both the expected loss and the variance, this principle attempts to ensure that the premium not only covers the average expected claims but also compensates the insurer for the risk and uncertainty inherent in underwriting insurance policies.>

**Query2: <How is the coefficient  $\alpha$  determined?>**

Output:

<The coefficient  $(\alpha)$  in the Mean-Variance Premium Principle, often referred to as the risk-loading factor, is not determined by a universal rule but is rather set based on the insurer's specific considerations and the nature of the insurance portfolio. Several factors influence the determination of  $(\alpha)$ , including:

1. **Risk Aversion of the Insurer:** More risk-averse insurers will choose a higher  $(\alpha)$  to ensure that the premium includes a higher risk margin. This compensates for the variability in potential losses and the insurer's discomfort with uncertainty.
2. **Market Conditions and Competition:** In a highly competitive market, insurers might be inclined to choose a lower  $(\alpha)$  to offer more attractive premiums. However, they must balance this with the need to remain solvent and profitable.
3. **Regulatory Requirements:** Insurance companies are often subject to regulatory requirements that dictate minimum capital levels and reserve requirements. These regulations might indirectly influence the choice of  $(\alpha)$  to ensure that the company remains compliant and financially stable.

4. **Historical Loss Data:** Insurers use historical data on claims and losses to estimate the expected loss and variance. A higher variance observed in historical data might lead to a higher  $\alpha$  to buffer against the higher uncertainty.
5. **Administrative Costs and Profit Goals:** The factor  $\alpha$  may also include considerations for covering administrative expenses, investment strategies, and the desired profit margin.
6. **Type of Insurance Product:** The nature of the insurance product (e.g., auto, health, property) also influences  $\alpha$ . Products with more volatile loss experiences may require a higher  $\alpha$  to account for the greater risk.
7. **Economic and Financial Conditions:** Broader economic and financial conditions, like the interest rate environment or economic volatility, can also impact the determination of  $\alpha$  as these factors influence the investment income from premiums and the overall risk profile of the insurer.

In practice, the determination of  $\alpha$  often involves actuarial judgment, statistical analysis, and strategic considerations. Insurers might use actuarial models, historical data analysis, and scenario testing to calibrate  $\alpha$  appropriately for their risk appetite and business objectives.>

### Query3: <What parts of Australia often experience extreme weather?>

Output:

<Australia's diverse climate leads to a variety of extreme weather conditions across different cities and regions. Here are some cities or areas known for their extreme weather, along with the specific climatic challenges they face:

#### 1. Darwin (Northern Territory):

- Experiences wet and dry seasons, with the wet season (November to April) bringing frequent thunderstorms, high humidity, and tropical cyclones.

#### 2. Brisbane (Queensland):

- Tropical cyclones and flooding during summer, especially in the Sydney Basin and coastal areas.
- High temperatures and humidity, particularly during summer.

#### 3. Sydney (New South Wales):

- Strong winds, waves, and East Coast Lows can cause coastal flooding.
- Increased risk of heatwaves and bushfires during summer.

#### 4. Melbourne (Victoria):

- Experiences extreme weather changes, including heatwaves, droughts, and occasional cold fronts.
- Winter cold fronts and cold streams can bring cold weather and strong winds.

#### 5. Adelaide (South Australia):

- High temperatures and drought, especially during summer.
- Strong winds and occasional maritime weather affecting coastal areas.

#### 6. **Perth (Western Australia):**

- Heatwaves and drought during summer.
- Winter storms and occasional tropical cyclones affecting northern areas.

#### 7. **Hobart (Tasmania):**

- Strong winds and storms in winter, especially influenced by Southern Low-Pressure Systems.
- Winter snowfall, especially in the highland areas.
- Cold streams bringing cold weather, particularly in winter.

These cities and regions reflect the vast and varied geographical landscape of Australia, with each area having its unique climate characteristics and associated challenges, from the tropical north to the temperate south.>

### **Query4:<What is a historic landmark in China's Hainan Province? >**

Output:

<Hainan Province, located at the southernmost part of China, is renowned not only for its beautiful beaches and tropical climate but also for its historic landmarks:

#### 1. **Haikou Five Officials Temple (Wugong Ci):**

- This ancient complex of temples in Haikou City was built to commemorate five famous officials from the Song Dynasty.
- The Five Officials Temple is not only a testament to Hainan's history but also a prime example of southern Chinese architecture.

#### 2. **Hainan Confucius Temple:**

- Although the Confucius Temple in Hainan is not as well-known as the one in Qufu, it still serves as an important cultural site that demonstrates respect for Confucius and his teachings.
- This temple often serves as a venue for cultural activities and festival celebrations for local scholars and residents.

#### 3. **The Old Town's Ancient Fort:**

- Located in an old town on the eastern part of Hainan Island, the ancient fort is symbolic of Hainan's defensive history.
- These forts were crucial military facilities for Hainan in defending against foreign invasions.

#### 4. **Yazhou Ancient City in Sanya:**

- With a long history, Yazhou Ancient City used to be a political, military, and cultural center of Hainan Island.
- The ancient city retains many historical relics, including city walls, ancient buildings, and cultural sites.

These landmarks not only showcase the rich history and culture of Hainan Province but also offer visitors to this beautiful island an opportunity to delve into the history of southern China.>

**Query5:<How to measure the cultural, historical, economic or community value of a building?>**

Output:

<Measuring the cultural, historical, economic, or community value of a building is a complex and multifaceted process that may require a combination of quantitative and qualitative assessments. Here are some methods and considerations for evaluating these aspects:

1. Cultural Value:

- a. Historical Significance: Determine the building's historical importance by researching its architectural style, age, past uses, and any notable events or figures associated with it. Historical significance can be measured on a scale from local to national importance.
- b. Architectural Significance: Evaluate the architectural design, uniqueness, and aesthetic value of the building. Expert opinions and architectural reviews can help in this assessment.
- c. Social and Symbolic Value: Examine the building's role in shaping the cultural identity of the community. Consider its cultural symbolism, use in ceremonies, or representation in art and literature.

2. Historical Value:

- a. Documentation: Conduct thorough historical research to uncover the building's history, including its construction, past owners, and any significant events that took place there.
- b. Preservation Status: Determine if the building is listed on local, national, or international historic registers, as this can be an indicator of its historical significance.

3. Economic Value:

- a. Property Value: Assess the property's market value, taking into account its location, condition, and potential for redevelopment.
- b. Revenue Generation: Consider how the building contributes to the local economy, such as through tourism, job creation, or income from rentals.

4. Community Value:

- a. Community Engagement: Consult with the local community to understand their perceptions and emotional attachment to the building. Surveys, public meetings, and community forums can be helpful.
- b. Utilization: Evaluate how the building is currently used by the community, such as for cultural events, social gatherings, or educational purposes.
- c. Social Services: Determine if the building provides essential services to the community, such as a community center, a place of worship, or a historical museum.

5. Expert Assessments:

- a. Seek the input of experts in architecture, history, and cultural heritage preservation to provide informed opinions on the building's value.
- b. Engage appraisers or real estate professionals to assess the building's economic value.

6. Comparative Analysis:

- a. Compare the building in question to similar buildings with known cultural, historical, economic, or community value to gauge its relative importance.

7. Cost-Benefit Analysis:

- a. Consider the costs associated with preservation or restoration against the potential benefits to determine if it is financially viable to protect the building.

8. Legal Protections:

- a. Research local, state, and national laws and regulations that may protect or designate the building as having cultural or historical significance.

Ultimately, evaluating the value of a building in these aspects may require input from various stakeholders, including historians, preservationists, community members, economists, and architects. It's important to take a holistic approach, considering both the tangible and intangible aspects of a building's value to make informed decisions regarding its preservation or redevelopment.>