

Research on Risk and Value Assessment under Extreme Conditions Based on Analytic Hierarchy Process and Delphi Method

Xiyu Yang *

Department of Business Administration, Xi'an International Studies University, Xi'an, China,
710128

* Corresponding Author Email: YANGxiyu1186@163.com

Abstract. With global climate change worsening, the property insurance sector faces growing challenges from increasingly severe extreme weather events. This paper pinpoints four key factors influencing insurance decision-making: disaster frequency, damage severity, consumer price index, and population dynamics. Analyzing data from ten countries, including China and the U.S., from 2014 to 2023, we establish a hierarchical evaluation model to assess these factors' correlations. Results show risk magnitudes of 0.925 for the U.S. and 0.982 for China, suggesting potential opportunities for insurance underwriting amid extreme weather. Using hierarchical analysis and the Delphi method, we assign weights to factors, identifying buildings scoring above three points as valuable and those with environmental indicator scores below 1.5 as needing protection. This approach aids in evaluating building value and protection requirements, assisting insurers in crafting informed risk management strategies.

Keywords: Analytic Hierarchy Process, Delphi Method, Insurance Model, Conservation Model.

1. Introduction

The surge in global climate change and the increasing frequency of extreme weather events pose unprecedented challenges to societal norms and economic stability. Insurance, a vital financial tool for risk mitigation [1], faces significant hurdles in coping with these escalating risks [2]. Recent trends underscore a notable rise in the severity and frequency of extreme weather phenomena, including floods, typhoons, heavy rains, and droughts, with far-reaching impacts on both human societies and architectural heritage [3]. These events entail various consequences, from human casualties to property losses and societal upheaval. Given this scenario, a thorough analysis of these trends and their implications becomes crucial for accurately assessing insurance risks and devising effective strategies for architectural preservation [4]. Architectural heritage, as a repository of historical, cultural, and economic values, not only reflects human history and achievements but also contributes significantly to economic development [5]. Therefore, safeguarding these invaluable assets from natural disasters is essential for societal sustainability.

To tackle climate change challenges and ensure China's economic and social stability, research focuses on assessing insurance risk and building protection, emphasizing evaluation methods and index system construction.

Evaluation methods include the Analytic Hierarchy Process (AHP) and the Delphi Method. AHP, pioneered by Saaty in the 1970s, hierarchizes decision-making elements to facilitate structured assessments [6]. For instance, Li Zheng (2023) applied AHP to evaluate supply chain finance risk [7]. The Delphi Method, developed by the RAND Corporation in 1946, relies on expert consensus [8]. Sun Ruiying and Li Jieru (2022) used it to assess personal privacy protection policies [9]. In constructing evaluation index systems, Lu Yaping (2023) developed a comprehensive system covering social, economic, environmental, landscape, architectural, and historical-cultural values, exemplified by Wuhan's Jiangnan Road and Zhongshan Road area [10]. Meng Qinghe and Lu Ming (2022) focused on community heritage in Hefei, analyzing its value and establishing an evaluation system to enhance urban historical heritage protection [11].

This study employs hierarchical analysis and the Delphi method to evaluate insurance risk and building protection needs in extreme weather conditions, aiming to devise adaptive strategies for risk management and building safety, thus contributing to novel pathways in this field.

2. Risk Assessment in Extreme Weather Insurance

2.1. Data Description

First, the study collected relevant data from ten countries around the world and then organized the data. The file contains data on the number of disaster occurrences, the amount of damage, the consumption index, and the population of China, the United States, India, Indonesia, Brazil, Thailand, Japan, Russia, France, and Mexico for the years 2014-2023, as shown in Table 1 (only the data for the year 2023 are shown here for reasons of space).

Table 1. 4 Statistical results for 10 countries in 2023

Corresponding Country	Number Of Disaster Occurrences	Amount Of Damage	CPI	Population
China	13	140235	102.0	1409670000
USA	22	145543167	298.0	335112000
India	18	3000	178.0	1395000000
Indonesia	15	2456000	103.5	278000000
Thailand	3	16300	107.7	70288415
Japan	6	143000	105.0	122420000
France	6	2135000	114.8	68043000
Brazil	16	3851200	6500.0	215000000
Russia	4	50000	234.0	146425000
Mexico	1	4000000	128.0	129345687

2.2. The establishment of an evaluation model based on the Analytic hierarchy process

2.2.1. Selection of Indicators

As climate change increases the likelihood of more severe weather and natural disasters, causing insurance companies to think about what kind of situations and when they should take on premiums, this study will take a hierarchical analytical model to evaluate and anticipate underwriting risk for insurance companies. The study identifies four key factors that influence the decision-making of insurance companies: the number of disaster occurrences, the amount of damage, the consumer price index, and the population, as shown in Figure 1. In extreme weather conditions, insurance companies should consider the above factors to develop reasonable premium rates and underwriting strategies to control risks and realize profits [12].



Figure 1. Indicator Chart

Number of Disaster Occurrences: If the number of disaster occurrences increases, the risk to the insurance company will also increase, which may increase premium rates or denial of coverage.

Amount of damage: If the amount of damage increases, the amount of compensation to be paid by the insurance company will also increase, which may also lead to an increase in premium rates or a refusal of coverage by the insurance company.

Consumer Price Index: An increase in the Consumer Price Index may result in an increase in premium income for insurance companies, as they may increase premium rates to cope with the upward pressure on costs. In addition, a rise in the CPI may also lead to an increase in the demand for insurance, which may boost the business growth of insurance companies.

Population: demographic factors can also have an impact on the decisions of insurance companies. If there is an increase in population, then the risk that the insurance company has to bear will also increase and hence it may increase the premium rates or refuse to underwrite the policy. Changes in demographics may also affect insurers' decisions, and if there is a significant trend of an aging population, then insurers may be under more pressure to pay out claims.

2.3. The solution of the evaluation model based on the Analytic hierarchy process

2.3.1. Analytic hierarchy process solution steps

(1) Create a hierarchy with objectives (risk factors) at the top, criteria (number of disaster occurrences, CPI, etc.) in the middle, and alternatives or weighted factors at the bottom.

(2) Pairwise comparisons are made for each factor in the middle tier, with the number of disaster occurrences being equally important as the amount of money affected, while the CPI is slightly less important than the first two, and the population is slightly less important than the CPI, the results are shown in Table 2.

Table 2. Indicator Index

Indicator	Number of Disaster Occurrences	Amount of Damage	CPI	Population
Number of Disaster Occurrences	1	1	3	5
Amount of Damage	1	1	1	1
CPI	0.333	1	1	1
Population	0.2	1	1	1

(3) Comparison of the weights of the factors such as the above was obtained through AHP analysis, resulting in a weighting calculation showing that the weight of the number of disaster occurrences was 44.243%, the amount of damage was 23.41%, the CPI was 16.831%, and the weight of population was 15.515%, the results are shown in Table 3.

Table 3. AHP hierarchical analysis results

Term	Eigenvector	Weighting (%)	Maximum characteristic root	CI value
Number Of Disaster Occurrences	1.77	44.243	4.264	0.088
Amount Of Damage	0.936	23.41		
CPI	0.673	16.831		
Population	0.621	15.515		

(4) Consistency test Calculate the consistency ratio (CR) to evaluate the consistency of the judgment matrix in Table 2. If it is less than 0.1 the result is acceptable. Otherwise, the pairwise comparisons need to be re-evaluated, the results are shown in Table 4.

Table 4. Consistency test results

Maximum characteristic root	CI value	RI value	CR value	Consistency test results
4.264	0.088	0.882	0.1	Pass

The above table exhibits the results of the consistency test. The above results lead to the final model.

2.3.2. Display of solution result

The study chose four indicators, namely, the number of disaster occurrences, the amount of damage, CPI, and population, and after finding the weights through hierarchical analysis, we came up with a formula for calculating the risk factor, to measure the underwriting risk of insurance companies. By analyzing the data, the results are shown in Table 5.

Table 5. AHP Analysis Result

Item	Eigenvector	Weighted Value (%)	Eigenvalue of Maximum	CI Value
Number Of Disaster Occurrence s(a)	1.77	44.243	4.264	0.088
Amount Of Damage (b)	0.936	23.41		
CPI (c)	0.673	16.831		
Population (d)	0.621	15.515		

From the above table, it can be seen that the number of disaster occurrences has the greatest weight, the greatest impact on the underwriting risk factor, and the most sub-population. The more disasters occur, the smaller the insurance company's underwriting risk, so it is negatively correlated with the risk factor, and finally the risk factor calculation formula:

$$\text{Risk Factor} = -0.44a + 0.23b - 0.16c - 0.15d \quad (1)$$

To ensure the correctness of the model, we later performed a consistency test, and the results are shown in Table 6 below:

Table 6. Consistency Check

The Largest Eigenvalue	CI Value	RI Value	CR Value	Consistency Test Result
4.264	0.088	0.882	0.1	Pass

After reviewing, CI is the consistency index, the larger the CI value, the more serious the inconsistency; RI is the stochastic consistency index, with the judgment of the evidence of the order, the larger the order, the greater the likelihood of the consistency of random deviation; CR is the consistency ratio, generally expressed as:

$$CR = \frac{CI}{RI} \quad (2)$$

$CR < 0.1$ means that the matrix consistency passes. From the data in the above table, $CI = 0.088$, which is close to 0 and the CR value is 0.1, this matrix consistency passes and the model passes the test.

2.4. Application of the model

2.4.1. Reasons for Area Selection

According to the global natural disaster assessment reports in recent years, Asia and North America have a high frequency of natural disasters, accounting for 40.87% and 18.80% of the total global frequency respectively, as shown in Figure 2, so the study selected one country per continent for model testing.

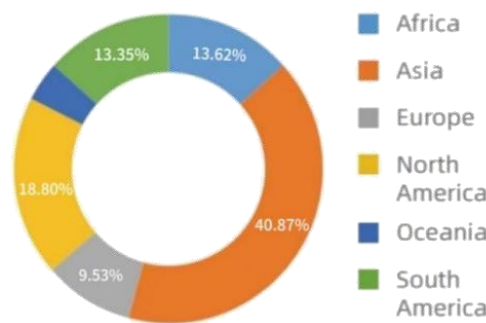


Figure 2. Statistics on the frequency of natural disasters

After investigation, it's evident that China and the United States boast diverse geographic environments and complex climatic conditions, ensuring the model's universality. Moreover, both countries have witnessed a surge in natural disasters in recent years, with an upward trend predicted for future extreme weather occurrences. Lastly, the mature development of the property and casualty insurance industry, coupled with government policy support and increasing premium revenues, indicates market growth potential in both nations, as shown in Figure 3 and Figure 4.

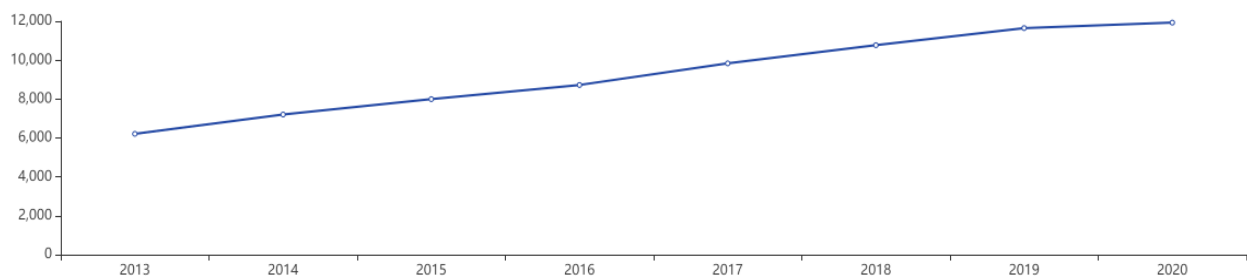


Figure 3. China property insurance income growth trend

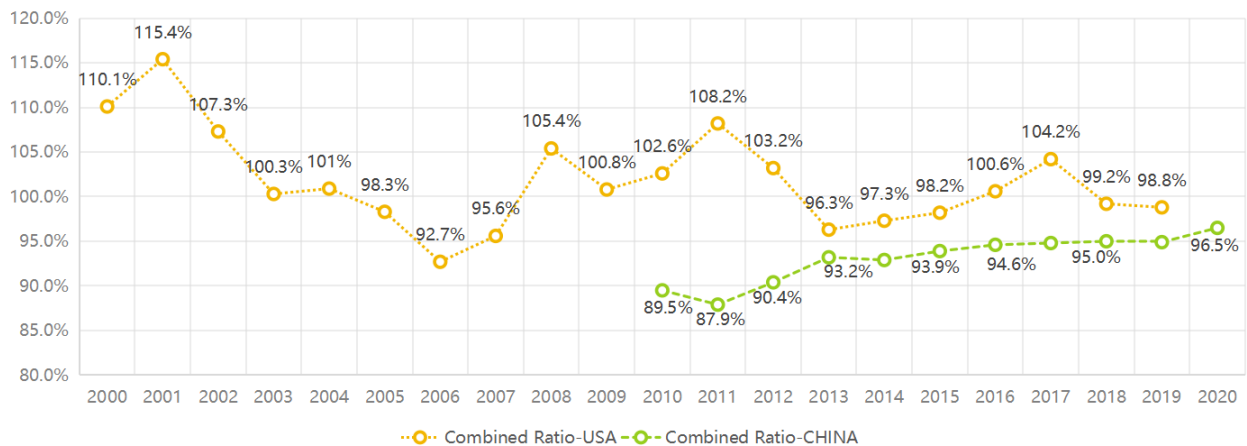


Figure 4. Sino-US property insurance comprehensive cost rate chart

2.4.2. Application of the two-site model

Predicting the values of the number of disasters in the two countries for the next five years through a time series yields the following data, as shown in Table 7.

Table 7. Predicted number of disasters over the next five years

Year	China	USA
2024	16	22
2025	17	25
2026	20	29
2027	14	31
2028	19	20

Afterward, the average value of the next five years (17 times, 26 times) of each indicator is used to measure the average trend after that, and the average value is brought into the model to find out the risk factor, and the risk factor of the two countries through the solution is 0.925 and 0.982, which is less than 1. Therefore, China and the United States have room for the development of property insurance for extreme weather, and the insurance company's underwriting risk is relatively low, and it can be chosen to underwrite the insurance.

3. Determining protection needs for buildings

3.1. Score modeling based on Analytic hierarchy process and Delphi method

3.1.1. Value evaluation and protection system establishment

The architectural value assessment and protection system is established based on a comprehensive approach encompassing historical and cultural significance, social value, economic impact, and environmental sustainability. Through hierarchical analysis, weights are assigned to each layer and indicator, followed by the Delphi method to score each indicator. Five qualified scorers provide scores to ensure data universality. The final score of a building is determined by multiplying the average scores of indicators with their respective weights. This score is then compared against predefined standards to determine if the building warrants protection. As shown in Figure 5, the evaluation system comprises three layers: the objective layer (A), the criterion layer (B), and the indicator layer (C), each contributing to a holistic understanding of architectural value.

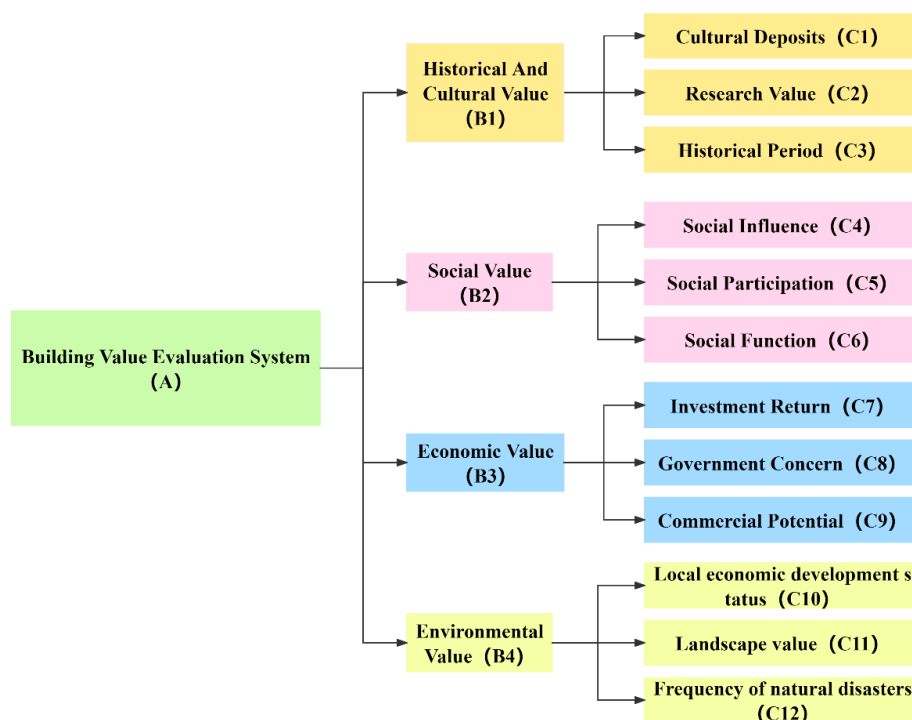


Figure 5. Value Evaluation System

3.1.2. Explanation of Indicators

Historical and cultural value encompasses the richness of cultural connotations within a building, the depth of historical research it facilitates, and the significance of its age. Buildings with profound cultural heritage, extensive research potential, and significant historical age are deemed to possess higher historical and cultural value, reflecting their contributions to preserving and showcasing the collective heritage of society.

Social value pertains to the building's impact on public consciousness, its role in fostering social participation and communication, and its ability to meet social needs and provide public services.

Buildings that are well-known, facilitate community engagement, and serve as platforms for public activities are considered to have higher social value, contributing positively to societal cohesion and well-being.

Economic value evaluates the building's potential for long-term preservation and appreciation, government support and investment, and commercial and tourism prospects. Factors such as return on investment, governmental concern and policies, and commercial viability determine the economic value of a building, influencing its significance in driving economic development and sustainability within its surrounding area.

3.2. Model resolution

3.2.1. Determination of indicator weightings

Distinguish the relationship between the relative importance of different indicators using the 1-9 scale (the meaning of which is shown in Table 8), and then construct a judgment matrix using the Delphi method for the evaluation of guidelines/programs.

Table 8. 1-9 scale method

Scale	Meaning
1	Both factors are equally important
3	the former factor is slightly more important than the latter
7	the former factor is more important than the latter
9	the former factor is extremely important than the latter
2, 4, 6, 8	The median value of the above adjacency judgments
Reciprocal	If the ratio of importance of factor I to factor J is Q, then the ratio of importance between J and I is 1/Q

3.2.2. Hierarchical single-ranking method to find the weights of each layer and each indicator

The target-criteria layer weights are calculated by the square root method, and the weights of the target-indicator layer are calculated by the sum-product method. Borrowing from SPSSPRO software, the weights of each indicator were calculated as shown in Tables 9 and 10:

Table 9. Weight of each indicator

Indicator	Wi
B1	0.218
B2	0.123
B3	0.072
B4	0.587

Table 10. Weight of each indicator

Factor	Wi	Factor	Wi
C1	0.117	C7	0.019
C2	0.065	C8	0.042
C3	0.036	C9	0.011
C4	0.017	C10	0.073
C5	0.029	C11	0.135
C6	0.077	C12	0.379

3.2.3. Consistency test

The consistency test was conducted on the judgment matrix models of the criterion and indicator layers, and the test results are shown in the table below. From the data in the table, it can be seen that the CR values of all matrix models are <0.1, which proves that all matrix judgment models pass the consistency test and the results are acceptable, the results are shown in Table 11.

Table 11. Consistency test results of 5 models

Model	The Largest Eigenvalue	CI Value	RI Value	CR Value	Consistency Test Result
Objective Level	4.019	0.006	0.882	0.007	Pass
B1	3.009	0.005	0.525	0.009	Pass
B2	3.018	0.009	0.525	0.017	Pass
B3	3.054	0.027	0.525	0.051	Pass
B4	3.004	0.002	0.525	0.004	Pass

3.2.4. Calculating the building score

(1) Indicator layer scores:

$$S_{C_i} = W_{C_i} * \frac{y_{C_i}}{5} \quad (3)$$

(2) Scores for each target level:

$$\begin{aligned} S_{B_1} &= (S_{C_1} + S_{C_2} + S_{C_3}) * W_{B_1} \\ S_{B_2} &= (S_{C_6} + S_{C_4} + S_{C_5}) * W_{B_2} \\ S_{B_3} &= (S_{C_9} + S_{C_7} + S_{C_8}) * W_{B_3} \\ S_{B_4} &= (S_{C_{11}} + S_{C_{10}} + S_{C_{12}}) * W_{B_4} \end{aligned} \quad (4)$$

(3) Overall building evaluation score:

$$Z = S_{B_1} + S_{B_2} + S_{B_3} + S_{B_4} \quad (5)$$

y_{C_i} is the sum of five expert scores for each indicator in the indicator layer, W_{C_i} is the weight of each indicator in the indicator layer, Z stands for the overall score of the building evaluation, and i takes the value range of [1,12].

3.3. Scoring criteria

The overall score of the building evaluation is full of 5 points, the study takes the overall score of the building to see, will be 3 points as the limit, 3 points and above is a valuable building. In the selection of the indicators of the environment in which the building is located, the study considers the risk to which the building is exposed (i.e., the probability of natural disasters), so the evaluation model also reflects whether the building needs to be protected or not. The study believes that buildings that are valuable and have environmental scores below a set standard need to be protected so that they do not lose their value. In the model, the highest environmental indicator score is 2.97, and this study uses a score of 1.5 as a criterion, so when the overall score of the building is greater than or equal to 3, and the score of the environment in which it is located is lower than 1.5, the building needs to be protected.

4. Conclusion

This study utilizes hierarchical analysis and the Delphi method to evaluate property insurance allocation strategies and building protection needs in the face of extreme weather. It begins by assessing whether insurance companies should underwrite areas prone to increased extreme weather, employing indicators like disaster occurrences, damage extent, CPI, and population dynamics. Validation in the U.S. and China shows risk factors below 1, indicating insurability. Furthermore, the study outlines criteria for identifying building value and protection requirements, considering historical, cultural, economic, and environmental aspects. This research offers a robust framework

for risk management and insurance science, aiding insurers in formulating strategies and building owners in understanding protection needs effectively.

Through hierarchical analysis and the Delphi method, this study systematically evaluates insurance risk and building protection needs under extreme weather conditions. It provides decision support for insurers in crafting underwriting strategies and assists building owners in understanding protection requirements. The proposed criteria comprehensively assess historical, cultural, economic, and environmental factors, facilitating the preservation of valuable architectural heritage in line with sustainable development principles.

References

- [1] Fang Yunlong, Lan Hong. Research on the Impact and Response of Climate-Related Risks on the Financial Sector [J]. *New Finance*, 2023 (06): 60 - 67.
- [2] GUO Xiaojie, LIU Shu. Who will "insure" the insurance industry against extreme weather? [N]. *21st Century Business Herald*, 2023 - 12 - 27 (008).
- [3] Liu Yanchunzi. How insurance companies can better manage climate risk [N]. *Financial Times*, 2023 - 08 - 15 (008).
- [4] Ma Zhengyu, Song Yujuan. Impact of climate change on financial stability: a theoretical explanation [J]. *Southern Finance*, 2023 (03): 19 - 36.
- [5] Wang Yang. Reflections on "building-site" design under the concept of resilience [J]. *Architecture and Culture*, 2023 (04): 1.
- [6] Saaty T L, Kearns K P. The Analytic Hierarchy Process [M]. *Analytical Planning*, 1985.
- [7] Li Z. Research on risk identification of bank supply chain financing business based on hierarchical analysis [J]. *China Market*, 2023 (17): 13 - 17.
- [8] DALKEY N, HELMER O. An experimental application of the Delphi method to the use of experts [J]. *Management Science*, 1963, 9 (3): 455 - 468.
- [9] SUN Ruiying, LI Jieru. Research on the Evaluation of Personal Privacy Protection Policy of China's Government Data Open Platform [J]. *Library and Intelligence Work*, 2022, 66 (12): 3 - 16.
- [10] Lu Yaping. Research on the value evaluation of historical and cultural neighborhoods based on hierarchical analysis method--Taking Jiangnan Road and Zhongshan Road piece in Wuhan as an example [C]//China Society of Urban Planning. *People's City, Planning Empowerment - Proceedings of 2023 China Urban Planning Annual Conference (09 Urban Cultural Heritage Protection)*. [Publisher unknown], 2023: 11.
- [11] MENG Qinghe, LU Ming. Evaluation of Community Heritage Value of Non-Historic Cities from the Perspective of 20th Century Architectural Heritage--Taking Hefei as an Example [J]. *Construction Economy*, 2022, 43 (S2): 499 - 503.
- [12] B.C. Hu, T. T. Tang, R. P. Wang. Analysis of factors affecting reinsurance demand of China's general insurance companies--an empirical study based on BP neural network method [J]. *Insurance Research*, 2012 (06): 3 - 12.