Ningbo Marine Ship Risk Assessment and Insurance Product Design Research

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Abstract. This study focuses on improving the risk assessment and insurance product design for marine vessels in Ningbo to meet complex shipping insurance needs and enhance market competitiveness. It analyzes the scale, product structure, operations, and risks of Ningbo's ship insurance market, identifying challenges such as product homogeneity, lack of innovation, and outdated risk management technologies. Using literature review, empirical analysis, and case comparison, the study provides theoretical and practical support for innovative product design. A multi-dimensional risk assessment system was established, incorporating Ningbo's marine environment characteristics like climate, ship types, and route complexity. Linear and generalized linear models identified key factors affecting ship insurance claims, leading to the proposal of a dynamic pricing strategy to adjust rates in real-time based on risk environment changes. The study advocates for differentiated and adaptable insurance products offering comprehensive protection. It highlights the integration of risk prevention and insurance, recommending value-added services like risk warnings and safety inspections. Preventive measures by enterprises would earn preferential rates, improving risk management and enhancing collaboration between insurance companies, shipping firms, and port authorities. It also suggests leveraging big data, AI, and blockchain for digital transformation and smart industry upgrades. These innovations aim to improve risk management, pricing accuracy, and promote high-quality, internationalized development of Ningbo's ship insurance market.

Keywords: Ocean Vessels; Risk Assessment; Insurance Products; Innovative Design.

1. Introduction

1.1 Origin of the Topic

In international trade, shipping is crucial. The Ningbo Municipal Government has proposed that by 2020, the scale of shipping insurance risk protection will exceed 1 trillion yuan to support the construction of the "Belt and Road". The policy aims to form new advantages in shipping insurance and build a complete shipping insurance industry base through institutional reform and innovation-driven. However, Ningbo's shipping insurance market faces challenges such as insufficient product innovation and lagging risk management technology, which affect its ability to support international trade. The basic fundamental of BP neural network [1].

1.2 The Current Research Situation

The analysis of ship insurance is based on the characteristics and status of shipping insurance. Leng Cuihua (2013) pointed out that there are relatively few insurance companies involved in ship insurance, and the monopoly of ship insurance is obvious. At the same time, there is excessive competition in the low-end market, and the profit of ship insurance business is low, which makes the business unattractive to insurance companies. Xu Miaomiao (2016) [1] also believes in his report and analysis that the large-scale and high-value ships are increasing the risks of ship insurers. However, due to market competition, the underwriting capacity, brand and ship insurance management level of small and medium-sized insurance companies are relatively weak, which makes it difficult for insurance companies to make profits in ship insurance [2].

The analysis is based on the business philosophy of ship insurance. Ding Bo (2013) pointed out from the perspective of insurance companies themselves that operating high-risk business such as ship insurance requires strengthening risk management from four aspects: regional positioning, underwriting and claims policy, and talent allocation, so as to achieve the business goals of scale and efficiency [3]. Song Fangxiu (2016) compared my country's shipping insurance industry with that of developed countries and pointed out that although my country's insurance industry has expanded rapidly in scale, it still has a large gap with developed countries in terms of development quality. He proposed that the development of shipping insurance requires improving the insurance industry system, cultivating high-end talents, strengthening the construction of shipping information platforms, attracting enterprises to insure domestically, improving innovation capabilities, and cooperating with major countries [4].

1.3 Research Methods

BP neural network is back propagating, mainly composed of three parts: input layer, middle layer and output layer. The number of nodes in the input and output layers is relatively easy to determine, but the determination of the number of nodes in the hidden layer is a very important and complex problem.

1.4 Research Ideas

On the basis of analyzing and summarizing the existing relevant research results, this paper combines the actual situation of Ningbo Port and innovatively uses relevant theoretical methods to carry out the research of this topic. By using literature research and analysis and actual investigation and interview communication, combined with the payment situation of shipping insurance companies in recent years, a payment risk factor identification model is constructed, and the risk factors affecting ship insurance payments are analyzed using a generalized linear regression model. The risk variable types are statistically expressed and carefully analyzed and compared, and finally the degree of influence and contribution rate of each risk factor on the payment ratio are determined. The results obtained by the regression model are empirically analyzed, and the risk factor identification model established above is empirically verified. The insured ship data is classified and the probability of each type of accident is further analyzed. The claim risk value of ship insurance is comprehensively evaluated, and the pricing strategy for ships of various risk levels is proposed in a targeted manner.

2. Theoretical Framework

2.1 Risk Management Theory

Risk management theory is a method system for systematic management of potential risks, which includes risk identification, risk assessment, risk response and other links.

2.2 Insurance Economics Theory

Insurance economics theory analyzes the operating mechanism and efficiency of the insurance market from an economic perspective. The theory of insurance demand and supply can be expressed by the following formula: insurance demand = f (risk aversion, wealth level, insurance price, etc.); insurance supply = f (operating costs, risk expectations, market competition, etc.).

2.3 Actuarial Theory

Actuarial theory mainly uses statistical and mathematical methods to quantify the probability of risk and the extent of loss. In ship insurance, the following formula can be used to calculate the insurance premium: Insurance premium = pure risk premium ÷ (1 - cost surcharge rate). Pure risk premium = expected loss amount × risk adjustment factor.

2.4 Generalized Linear Model Theory

The generalized linear model (GLM) is a natural extension of the linear regression model, first proposed by Nelder and Wedderburn in 1972. It makes the overall mean of the dependent variable depend on the linear prediction value through a nonlinear link function, and allows the probability distribution of the response variable to belong to any member of the exponential distribution family. Widely used statistical models such as logistics regression, Poisson regression, negative binomial regression, and Probit regression are all specific applications of generalized linear models.

2.5 Cross-analysis and Multi-causal Relationship Theory

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3. Construction of Ningbo Marine Ship Risk Assessment Model

3.1 Ship Insurance Claims Data Processing

This article uses the insurance claims data of a shipping insurance company in the past six years as the source. DH is a national shipping insurance company that covers a wide range of ship types and numbers. The research data includes 35,000 underwriting data and 7,819 claims data, covering key information such as ship name, tonnage, insured amount, and accident type. In order to simplify the data processing process, this article only retains the core variables that have the greatest impact on compensation: ship age, tonnage, ship type, insured amount, and accident type. Through preliminary cleaning and matching of the data, incomplete or duplicate data were deleted, and finally 15,694 valid underwriting data and 2,618 claims data were screened out. Specific risk assessment indicators include the age, type, technical condition, equipment maintenance, crew qualifications and experience, complexity of navigation areas and routes, meteorological and sea conditions, safety management system and implementation of ship management companies, insurance history and claims records of ships, etc. For each indicator, its definition, measurement method and value range are further clarified to facilitate accurate quantitative evaluation.

3.2 Variable Description and Descriptive Statistics

Dry cargo ships accounted for the highest proportion of underwriting and claims, at 60.6% and 65.8% respectively, showing their dominant position. The proportion of claims for container ships was higher than that for underwriting, and the accident rate was higher. Touch and collision were the most common causes of accidents, accounting for 23.3% and 21.4% respectively, followed by mechanical parts damage, accounting for 18.2%. "Other accidents" accounted for 8.9%, partly due to incomplete or inaccurate information entry. Ships of 1001-3000 tons had the highest frequency of accidents in underwriting and claims, accounting for 40.7%. Ships with an age of 0-5 years and over 25 years had a lower frequency of accidents and lower risks.

The maximum compensation amount is 14551368.80 yuan, and the minimum value is 0. The gap between the two is quite large. At the same time, the standard deviation is 682186.53, the skewness coefficient is 12.86, and the peak value is 201.50.

3.3 Model Building

This paper mainly considers the impact of five variables, namely, ship age, tonnage, ship type, accident type, and insured amount, on the amount of compensation. At the same time, the amount of compensation for each policy will also be limited by the insured amount. Therefore, this paper takes the insured amount as a covariate and constructs the regression equation as follows:

$$\ln Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 \tag{1}$$

In the above formula, Y represents the compensation amount, X_1 represents the age of the ship, X_2 represents the tonnage, X_3 represents the type of ship, X_4 represents the type of accident, and X_5 represents the insured amount. $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ Represents the relevant coefficient, and the formula can be transformed to obtain:

$$Y = \exp(\beta_0) \cdot \exp(\beta_1 X_1) \cdot \exp(\beta_2 X_2) \cdot \exp(\beta_3 X_3) \cdot \exp(\beta_4 X_4) \cdot \exp(\beta_5 X_5) \tag{2}$$

3.4 Model Empirical Analysis

From the empirical results of the model, it can be concluded that ship age, ship registered gross tonnage, accident type, ship type, and insurance amount all significantly affect the compensation amount at the 1% level. Since there are many dependent variables, this article will describe the regression results by category.

(1) Tonnage

Judging from the regression results, each range of the registered gross tonnage of the ship significantly affects the compensation amount at the 1% level. Compared with ships above 20,000 gross tonnage, except for the range of 30,001-5,000 which has a greater impact on the compensation amount, other factors have a greater impact on the compensation amount. The degree of impact is relatively small. Based on the regression results, the impact multiple of each tonnage range on the compensation amount is calculated.

(2) Age of ship

From the perspective of ship age, taking ships over 25 years old as the reference group, the empirical results show that with the increase of ship age, the risk multiple of claims also gradually increases, and the risk multiple of ships over 25 years old is the highest. This also explains why both direct insurance companies and reinsurance companies are reluctant to insure ships over 25 years old and set them as contract exceptions. After converting the β value through the exp function, the multiple of the impact of each age on the claim amount is obtained.

4. Ningbo Ship Insurance Product Design

4.1 The Core Framework of Pricing Strategy

The insurance pricing strategy of this study is divided into several main parts: basic premium, additional risk rate, dynamic adjustment mechanism, and refined processing of actuarial model. The final premium formula is:

$$P = B_0 \cdot \left(1 + \sum_{i=1}^{n} R_i\right) \cdot A + D + C \tag{3}$$

Among them, P is the final premium, B_0 is the basic premium, which is set based on the basic information of the ship. R_i is the additional risk factor, which covers multiple factors, including ship type, tonnage, age, navigation area, and classification society certification. A is the dynamic adjustment coefficient, which is dynamically adjusted based on time, season, and real-time risks (such as typhoon season, ship location, etc.). D is the experience adjustment coefficient, which is adjusted based on historical claims records and the shipowner's operational safety record. C is the operating cost and profit surcharge.

4.2 Basic Premium (B_0) Calculation

The basic premium calculation is based on the core attributes of the vessel, including age, tonnage and vessel type. The calculation is based on a weighted risk factor formula:

$$B_0 = B_{min} \times \left(1 + \alpha_1 f_{\text{age}} + \alpha_2 f_{\text{tonnage}} + \alpha_3 f_{\text{type}}\right) \quad (4)$$

Where B_{min} is the base premium, which is the minimum premium for all ships and is set as the basic protection cost of the insurance company. α_1, α_2, α_3 are the weights of the risk factors, based on the calculations in the previous section. f_{age}, $f_{tonnage}$, f_{type} are the risk coefficients of ship age, tonnage, and ship type, respectively.

(1) Ship age risk factor(f_{age})

Age	0-5years	6-10years	11-15years	16-20years	21-25years	above25years
f_{age}	0.5	0.4	0.3	0.2	0.15	0.1

(2) Tonnage risk factor($f_{tonnage}$)

Tonnage (tons)	0-1000	1001-3000	3001-5000	5001-20000	Above 20000
$f_{tonnage}$	0.1	0.2	0.3	0.4	0.3

(3) Ship Type Risk Factor (f_{type})

Vessel Type	container	Dry cargo	RoPax	Liquefaction	Tugboat
f_{type}	0.5	0.4	0.4	0.3	0.3

4.3 Additional Risk Rate ($\sum_{i=1}^{n} R_i$)

The additional risk rate reflects the additional risk of the ship, including the following key factors: navigation area, classification society certification, accident type, and seasonal risk.

Accident type risk ($R_{accident}$)

Vessels with a higher risk of collision: $R_{accident} = 0.3$; Vessels with a higher risk of fire or explosion: $R_{accident} = 0.25$; Other common risks (such as grounding): $R_{accident} = 0.2$

Seasonal risk (R_{season})

Typhoon season: $R_{season} = 0.2$; Non-typhoon season: $R_{season} = 0$

4.4 Dynamic Adjustment Mechanism (A)

For shipowners with good safety records, the premium can be appropriately reduced as an incentive mechanism: 10% reduction in premiums for 5 consecutive years without major accidents. Rongguang Internet of Things (loL) technology and real-time monitoring system, ships entering high-risk areas (such as frequent pirates or storm centers): premiums increase by 10%.

4.5 Experience Adjustment Factor (D)

The experience adjustment coefficient is mainly used to increase the rates for shipowners with high-frequency accidents based on past compensation records, or to make appropriate adjustments for shipowners with low accident rates. The specific adjustment formula is as follows:

$$D = \frac{1}{N} \cdot \sum_{j=1}^{N} \left(\frac{C_j}{S_j}\right) \quad (5)$$

Where N is the number of claims in the past five years. C_j is the amount of compensation for the jth accident. S_j is the insured amount of the ship. D is the rate multiple adjusted by the historical claim record. If the claim rate in the past five years is high, the coefficient will be adjusted upward. Otherwise, an appropriate discount will be given.

5. Conclusion

This study focuses on the risk assessment and insurance product design of Ningbo marine ships, combines theoretical and empirical analysis, and proposes a personalized insurance product innovation plan. Through the generalized linear model and multidimensional risk assessment system, based on the 6-year underwriting and claims data of a shipping insurance company, the impact of risk variables on claims is studied, and finally the impact and contribution rate of each risk factor on the claims ratio are determined. The results obtained by the regression model are empirically analyzed, and the risk factor identification model established above is empirically verified. The insured ship data is classified and the probability of each type of accident is further analyzed. The claim risk value of ship insurance is comprehensively evaluated, and the pricing strategy for ships of different risk levels is proposed. In terms of pricing strategy, a dynamic adjustment mechanism is proposed. Through multiple surveys and modeling, a flexible premium adjustment plan is proposed. In addition, by introducing an accident prevention incentive mechanism, it is recommended to provide premium reduction incentives for shipowners who adopt active risk management. During the research process, the limitation of data acquisition affects the market size and the accuracy of risk assessment. The complexity and dynamics of the ship insurance market may limit the research model and method. Future research can expand data sources, improve data quality, use more advanced data analysis methods, strengthen research on emerging risk factors, improve the risk assessment indicator system, and conduct in-depth research on policy formulation and implementation mechanisms.

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