A Study on Risk Assessment of Non-economic Factors of an Accident Based on Monte Carlo Simulation

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Abstract. This paper makes a systematic analysis of the losses caused by accidents and disasters and models the non-economic factors of an accident. Based on a brief introduction to traditional analysis methods, we introduced Monte Carlo simulation. This paper further analyses the application of the model by taking a concrete case as an example, verifying the practicability and scientificity of the model. This paper introduce and analyse the principle and superiority of Monte Carlo method, and combine the three links of risk analysis to analyse the implementation process of this method for non-economic factors risk analysis simulation. The analysis framework includes the basic ideas of each step of risk analysis under Monte Carlo simulation, the applicable methods of each step, and the selection of evaluation indicators. This method is scientific, reasonable and easy to operate, and could be applied in similar cases to provide a more scientific risk assessment for non-economic factors.

1. Introduction

Accidents and disasters have been accompanied by the mankind since ancient times. According to their influence on human society, the risk events caused by accidents or disasters can be roughly divided into two categories: one is the events that can be directly measured in currency, such as physical objects, property and other tangible things of value; the other is the events that cannot be directly measured in currency, but measured by non-economic factors, such as life, health, environment and goodwill [1]. This paper introduces several risk assessment methods for these non-economic factors by focusing on how to carry out risk assessment against value factors that cannot be measured in currency based on Monte Carlo simulation.

Accidents and disasters are major hidden dangers to our personal safety. In order to reduce casualties or further reduce the damages to property or environment when an accident or disaster occurs, it is necessary to explore how to assess the non-economic factors such as life, health, environment and goodwill in an objective and reasonable way.

However, a systematic analysis of numerous domestic and foreign literatures on quality improvement reveals the problem of insignificant input and output effects in the implementation of product quality improvement plan [2]. The cause is the lack of a comprehensive, objective and scientific method for evaluating the effectiveness of the quality improvement plan. Therefore, how to transform the implicit management ideas of quality management and quality improvement into intuitive and explicit evaluation is the focus of study in this paper. Since the product quality improvement plan involves the quantifiable cost and benefit indicators and the unquantifiable descriptive subjective evaluation indicators, this paper introduces the actor analysis method combining
subjective evaluation with objective evaluation to solve the problem in effectiveness evaluation of product quality improvement plan [3].

2. Traditional Risk Assessment Methods for Non-economic Factors
Risk management experts and economists have long been concerned about the risk assessment of non-economic factors. At present, the following methods are available for calculating relevant values.

2.1 Human-capital Method
The human-capital method describes that the value of a person’s life is the present value of his expected future earnings [4]. The expression formula is:

\[ V_x = \sum_{n=x}^{\infty} (p_x^n) \cdot (p_x^n) \cdot (p_x^n) \cdot Y_n / (1 + r)^{n-x} \]  

Where, \( V_x \) is the present value of the total future earnings of a person aged \( x \);
\((p_x^n)\) is the probability of the person to live to age \( n \);
\((p_x^n)\) is the probability of the person to work within age \( n \);
\((p_x^n)\) is the probability that the person is employed during the period when he has the ability to work within age \( n \);
\( Y_n \) is the earnings of the person at age \( n \); and \( r \) is the discount rate.

2.2 Work Value Estimation Method
Another formula is put forward in China at present to calculate the value of life based on the value created by work:

\[ V_h = D_H \cdot P_{V+m} / (N \cdot D) \]  

Where, \( V_h \) is the value of life of a person, in RMB 00'000;
\( D_H \) is the average workdays of a person in his life, which is generally 12,000 days;
\( P_{V+m} \) is the net output value of theenterprise in the previous year, in RMB 00'000;
\( N \) is the number of employees in the enterprise in the previous year; and
\( D \) is the number of statutory workdays provided by the enterprise in the previous year, which is generally 250-300 days [5].

3. Process of Risk Assessment for Non-economic Factors based on Monte Carlo Simulation
Monte Carlo simulation, also known as random sampling or statistical test method, is a branch of computational mathematics [6]. Traditional empirical methods can hardly produce satisfactory results because they are not able to approach the real physical process, while the Monte Carlo method can solve the problem because it can realistically simulate the real physical process if a probability model or probability distribution is available. Therefore, simulation with a mass of data could make the problems to be solved closer to reality [7]. Monte Carlo method is a method to solve problems by generating appropriate random numbers and observing data that obeys some specific properties or attributes. It provides approximate solutions for various mathematical problems through statistical sampling experiments on computers. This method is very effective for some problems that are too complex to analyse and obtain a numerical solution, and it is also suitable for problems with no probability and inherent probability deconstruction. In recent years, with the rapid development of computer technology, the use of Monte Carlo simulation methods for stochastic simulation has been more widely used. Therefore, research on the application of Monte Carlo methods has become more important.

Life insurance compensation requires an objective and reasonable estimation of the value of a person. We are researching various methods to evaluate non-value factors. More reasonable parameters need to be selected to evaluate the results. For example: self-assessment of internal
employees, assessment of senior management of the enterprise, assessment of other enterprises in the industry. These parameters are based on facts and experience [8].

3.1 Identification of Study Background and Data Sources
We illustrate the application of Monte Carlo simulation in this field through quantitative analysis of the value of life related to non-economic factors. This paper focuses on the assessment of the value of life related to non-economic factors in the absence of express provisions and excludes that in industries having express provisions (because it is clearly stipulated in these industries) [9]. The data sources of the case in this paper include the judgments of similar cases in recent years and the estimates made by professionals.

3.2 Data Sources and Preprocessing
On this background, we illustrated how to solve the problems of this type by taking an example that "an employee of Company A died on business and Company A has to make compensation for it." How to make the compensation reasonably? We modeled three elements - Statuses A, B and C - through data statistics and field investigation (the value of life related to non-economic factors estimated by company executives and employees and other similar companies) [10]. For the sake of simplicity, we assumed that the estimated probability distribution under each status was standard normal. The average compensation amount (in RMB 00'000), standard deviation, and the most pessimistic, most possible and most optimistic estimated compensation amounts under each status are shown in table 1 Data Sources below:

| Status | Pessimistic | Most Possible | Optimistic | Mean value | Standard deviation |
|--------|-------------|---------------|------------|------------|--------------------|
| A      | 10          | 40            | 80         | 41.66667   | 11.66667           |
| B      | 15          | 35            | 100        | 42.5       | 14.16667           |
| C      | 20          | 50            | 120        | 56.66667   | 16.66667           |

3.3 Data processing
Next, we quantitatively analyzed the optimal value of the compensation amount through Monte Carlo simulation. We simulated this case with Excel and shown in table 2 Simulation process below.

(1) We randomly selected the compensation amount under each status as input (as the compensation amount under each status was not constant and itself was an estimated distribution interval).

| Status | Pessimistic | Most Possible | Optimistic | Mean value |
|--------|-------------|---------------|------------|------------|
| A      | 50          | 41            | 62         |            |
| B      | 54          | 44            | 43         |            |
| C      | 40          | 49            | 49         |            |
|        | 52          | 44            | 63         |            |
|        | 36          | 20            | 50         |            |
|        | 44          | 46            | 65         |            |
|        | 32          | 36            | 52         |            |
|        | 25          | 58            | 60         |            |
42  34  45  
27  25  52  
47  35  85  
46  48  81  
38  30  54  
17  53  78  
45  33  55  
45  44  57  
42  24  74  
36  61  56  
37  66  52  
24  48  55  
26  34  63  
31  68  63  
49  16  56  
39  18  50

(2) We simulated the case as many as possible to get the final optimal compensation amount. In this case, we selected 72 sets of simulation values only.

(3) We then performed random simulation analysis against these compensation amount values obtained to get the probability distribution of the final compensation amount estimates which is shown in figure 1 Monte Carlo simulation analysis.

![Random Simulation Analysis](image)

**Figure 1.** Monte Carlo simulation analysis

### 3.4 Data Analysis

After the above data processing, we analysed the meanings of the simulation results in figure 1, we can draw conclusions intuitively. The minimum and maximum compensation amounts in random simulation were RMB 100,000 and RMB 900,000 respectively. The cumulative frequency reached the maximum when the compensation amount was RMB 700,000. Therefore, we consider that the
compensation amount of RMB 700,000 could meet the psychological expectation of most people in light of the predetermined study background and data sources according to random simulation results [11].

4. Brief Summary
We simulated and analysed the value of life related to non-economic factors based on Monte Carlo simulation. Our data statistics and field investigation data may help enterprises choose the optimal solution among numerous alternatives, which will not only reduce legal risks, but also facilitate assessment to some extent in case of massive and complex data. The study results of this paper are scientific and practical, and provide methodological support for enterprises in risk management.

Acknowledgements
We would like to acknowledge that this Study is supported and funded by the Market Supervision Technology Assurance Project under Grant No. 2020YJ043, the National Science Foundation of China under Grant No. 91646122, 91746202, the Basic Scientific Research Business Projects 552018Y-5927-2018.

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