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Gray Correlation Analysis of Coal Mine Accidents

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Abstract: Based on the statistics of 2008-2012 State Administration of study safety coal mine accident,a grey relational analysis model of coal mine accidents was established,and the grey correlation matrixes were established according to the grey relevance degree of data series. The gas accident, roof accident and flood accident were considered as the main influential factors according to the advantage analysis method. The analysis method provides scientific basis for further prevention and control of coal mine accidents as well as strengthening coal mine safety production management.

Key words: Grey correlation analysis model, grey system, correlation coefficient, coal mine accident

INTRODUCTION

In recent decades, coal mine accident occurred frequently recent in China, it has always been a major bottleneck to the development of coal industry and a big threat to the property and life. In order to rightly analyze and summarize the reason and rule of the coal mine accidents, the grey relevant method (Gu and Zhao, 1996; Liu and Jiang, 2005; Li and Liu, 2006) was applied to calculate the main influential factors based on the statistics of 2008-2012 State Administration of study safety coal mine accident. The analysis result provides scientific quantitative basis for the prevention of coal mine accidents and the strengthening safety management. The analysis result provides scientific quantitative basis for the prevention of coal mine accidents and the strengthening safety management.

GREY CORRELATION ANALYSIS MODEL

Grey correlation analysis (Liu and Guo, 2000) is a measure of the correlation between two factors in the system and it describes the situation of relative changes between factors in the process of system development, such as the relative changes of size, direction and speed. It is a method, which can determine the influence degree between factors in the system and the factor contribution to system main behavior.

Original data sequence: It is supposed that there is a reference sequence which is marked as $Y_0 = [Y_0(1),Y_0(2),Y_0(3), \ldots ,Y_0(n)]$. At the same time, there is a sub sequence which is recorded as $Y_1, Y_2, Y_3, \ldots, Y_m$. The sub factors sequence is used to compare with the reference sequence:

- $Y_1 = [Y_1(1),Y_1(2),Y_1(3),\ldots,Y_1(n)]$
- $Y_2 = [Y_2(1),Y_2(2),Y_2(3)?\ldots,Y_2(n)]$
- $Y_3 = [Y_3(1),Y_3(2),Y_3(3),\ldots,Y_3(n)]$
- $Y_m = [Y_m(1),Y_m(2),Y_m(3),\ldots,Y_m(n)]$

Average processing of the raw data: In practice, the data dimension is often different from the absolute value of the value. Therefore, it is necessary to transform the data into a dimensionless and unification. This article adopts the method of average processing to transform the original data.

Average processing means that every date is divided by average data of each list, from which a new sequence can been obtained. This method is suitable for the cluttered data sequence and it can reduce the effect caused by the first data's instability to some extent. The original data is processed (initialization, normalization) as below:

$$\begin{aligned} X_0 &= Y_0(k)/\frac{1}{n}\sum_{k=1}^{n} Y(k) \\ X_i &= Y_i(k)/\frac{1}{n}\sum_{k=1}^{n} Y(k) \end{aligned} \tag{1}$$

In the above formula, i = 1, 2, 3, …, m; k = l, 2, 3, …, n. After transformation, the original data sequence is:

- $X_0 = [X_0(1), X_0(2), X_0(3), \ldots, X_0(n)]$

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- $X_1 = [X_1(1), X_1(2), X_1(3), \ldots, X_1(n)]$
- $X_2 = [X_2(1), X_2(2), X_2(3), \ldots, X_2(n)]$
- $X_m = [X_m(1), X_m(2), X_m(3), \ldots, X_m(n)]$

The calculation steps of the correlation coefficient The previous data is used to calculate the different sequence, which can been marked as:

$$\Delta_i(k)=|X_0(k)-X_i(k)| \ (i=1, 2, \ldots, m)$$
$$\Delta_i=[\Delta_i(1),\Delta_i(2), \ldots, \Delta_i(n)] \quad (2)$$

where, to calculate the maximum and minimum values of the difference sequence, it is marked as:

$$\Delta_i(\max) = \max_i \max_k \Delta_i(k)$$
$$\Delta_i(\min) = \min_i \min_k \Delta_i(k)$$

where, correlation coefficient between X_0 and X_i (i = 1, 2, ..., n) is defined as:

$$\xi_i(k)=\frac{\min_i \min_k |x_0(k)-x_i(k)| + \varepsilon \max_i \max_k |x_0(k)-x_i(k)|}{|x_0(k)-x_i(k)| + \varepsilon \max_i \max_k |x_0(k)-x_i(k)|} \quad (3)$$

where, in the above formula, $\xi_i(k)$ is called the correlation coefficient which corresponds to the moment of k; ϵ is distinguish coefficient whose value range is [0, 1]. Different value of ϵ is often corresponding to the different correlation degree and it can improve the differences in correlation coefficient. The value of ϵ is generally difficult to affect the correlation degree. It is theoretically proved that the smaller the ϵ, the higher the resolution and the value of ϵ is usually defined as $\varepsilon = 0.5$. The correlation degree (Liu and Dong, 2012) between X_0 and X_i can been obtained by averaging the $\xi_i(k)$:

$$v_i=\frac{1}{n}\sum_{k=1}^{n}\xi_i(k) \quad (4)$$

where, in the analysis of correlation degree of coal mine accidents, correlation degree reflects the influence of various factors on the death number of coal mine accident. The large value of V_i illustrates that the factor of X_i has a great effect on the accident of X_0.

ANALYSIS OF COAL MINE ACCIDENT GREY CORRELATION

Based on the statistics of 2008-2012 State Administration of study safety coal mine accident, the influence factors of coal mine accidents can been divided into seven types as below: gas accident, roof accident, mechanical and electrical accidents, transportation accidents, flood accident, fire accident and blasting accident. The death number of coal mine accident every year and the number of death in coal mine accident of various categories shown in Table 1 are taken as reference series Y_0 and compared series Y_i(I = 1, 2, ..., 7), respectively. The data given in Table 1 can been used to analyze grey correlation degree of coal mine accident.

The data in Table 2 is obtained by using the average method Eq. 1 to deal with the raw data in Table 1, namely using the dimensionless processing method. The different sequence result shown in Table 3 is calculated by Eq. 2.

The correlation coefficient of the coal mine accident of each type is obtained by Eq. 3 and the result is given in Table 4.

The correlation degrees for each type of coal mine accident are calculated by Eq. 4, as $V_1 = 0.9148$, $V_2 = 0.9656$, $V_3 = 0.4816$, $V_4 = 0.7028$, $V_5 = 0.7529$, $V_6 = 0.5922$, $V_7 = 0.7017$.

Table 1: Raw statistics of coal-mining fatalities

Accident type	2008	2009	2010	2011	2012
Gas (Y_1)	351	413	291	288	212
Roof (Y_2)	38	34	22	25	22
Mechanical and Electrical (Y_3)	32	114	118	14	11
Transportation (Y_4)	38	25	10	42	41
Flood (Y_5)	241	101	66	142	131
Fire (Y_6)	94	19	111	0	25
Blasting (Y_7)	47	7	5	12	3
Total (Y_0)	841	713	551	523	445

Table 2: Dimensionless processing result

Dimensionless sequence	2008	2009	2010	2011	2012
X_0	1.37	1.16	0.90	0.85	0.72
X_1	1.13	1.33	0.94	0.93	0.68
X_2	1.35	1.21	0.78	0.89	0.78
X_3	0.55	1.97	2.04	0.24	1.19
X_4	1.22	0.80	0.32	1.35	1.31
X_5	1.77	0.74	0.48	1.04	0.96
X_6	1.89	0.38	2.23	0.00	0.50
X_7	3.18	0.47	0.34	0.81	0.20

Table 3: Different sequence result

	2008	2009	2010	2011	2012
Δx_1	0.239	0.167	0.039	0.075	0.042
Δx_2	0.021	0.046	0.116	0.036	0.056
Δx_3	0.815	0.812	1.145	0.609	0.466
Δx_4	0.151	0.359	0.576	0.495	0.590
Δx_5	0.401	0.419	0.412	0.192	0.238
Δx_6	0.519	0.779	1.332	0.851	0.222
Δx_7	1.807	0.687	0.559	0.040	0.521

Table 4: Correlation coefficient calculation results

	2008	2009	2010	2011	2012
ξ_1	0.809	0.863	0.980	0.945	0.977
ξ_2	1.000	0.974	0.906	0.984	0.963
ξ_3	0.538	0.539	0.045	0.611	0.675
ξ_4	0.877	0.732	0.625	0.661	0.619
ξ_5	0.709	0.700	0.703	0.844	0.810
ξ_6	0.650	0.550	0.413	0.527	0.821
ξ_7	0.667	0.581	0.632	0.980	0.649

The order of grey correlation degrees is $V_2>V_1>V_5>V_4>V_7>V_6>V_3$. From the above result, it can be seen that X_2 affects the X_0 most and the development trend of X_2 is nearest to X_0. Instead, X_3 is the last factor that correlates with X_0. It can be seen that the sequence of the effect of coal mine accident on the death toll is $Y_2>Y_1>Y_5>Y_4>Y_7>Y_6>Y_3$. In other word, the gas accident, roof accident and flood accident are considered as the three main influential factors in coal mine accident.

CONCLUSION

Based on the statistics of 2008-2012 State Administration of study safety coal mine accident,the gas accident, roof accident and flood accident are regarded as the main influential factors which are calculated by the grey correlation analysis method. The gas accident, roof accident and flood accident were considered as the main influential factors according to the comparative advantage analysis. The calculated result validates that the grey correlation coefficient is a feasible method to explore the rule of coal mine accident and it can provides guarantee for safety production of coal mine. Besides, the grey correlation analysis method can reduce the loss of state property and personal injury to the least extent.

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