Analysis of the Correlation Degree between Safety Condition and Influencing Factors of Heavy Machinery

IOP Conf. Series: Materials Science and Engineering **542** (2019) 012065 doi:10.1088/1757-899X/542/1/012065

Analysis of the Correlation Degree between Safety Condition and Influencing Factors of Heavy Machinery

Hongqi Luo[1] and Xia Liu[2*]

1 School of Material and Mechanical Engineering, Beijing Technology and Business University, Beijing, China
2 Quality Management Branch of China National Institute of standardization, Beijing, China
E-mail: lhqfrq@126.com
*Corresponding author

Abstract. It is important to research the relationship of safety condition and its influencing factors in heavy machinery industry. The influence level of factors on the death toll in ten thousand special equipment is analysed, which includes the main business income of heavy machinery, standard quantity, operators of special equipment, number of safety supervision organization and accident frequency. The correlation degree between the accident frequency and the death toll in ten thousand special equipment is 0.699, while the correlation degree for standard number, special equipment operators and safety supervision organization is 0.540, 0.514 and 0.512, respectively. The accident frequency has the most significant impact on the death toll in ten thousand special equipment, followed by the standard number, special equipment operators and safety supervision organization, while the main business income has the least impact. It shows that promoting local legislation and standards are conducive to improving the safety condition of heavy machinery in China.

1. Introduction

Heavy machinery industry is a combination of metallurgical machinery, heavy forging machinery, mining machinery, material handling machinery manufacturing and large-scale casting and forging manufacturing. According to the standard of GB/T 4754-2011 "Classification of National Economic Industries", the industrial sub-categories of heavy machinery industry have been changed from the original metallurgical equipment, mining equipment, lifting and transportation equipment to metallurgical equipment, mining machinery, light and small lifting equipment, cranes and production vehicles, continuous handling equipment, Elevator escalators and elevators and other material handling equipment. The death toll in ten thousand special equipment is used to represent the index of safety condition, while the influencing factors mainly include the main business income, the accident frequency, the number of safety supervision institutions and the number of relevant standards.

2. Statistics Selection and Data Collection

Choosing different statistical indicators for the safety condition of heavy machinery and its influencing factors will have some influence on the calculation results, but there is generally the same proportion relationship between different calibre data[1].

The main business income is used to represent the main economic indicators of heavy machinery industry, which refers to the business income of enterprises engaged in the production and operation activities of the industry. The relevant data of special equipment was selected to represent the number of safety accidents and casualty data indicators through referring the "China Heavy Machinery Industry

Yearbook" from 2009 to 2017[2]. Special equipment refers to boilers, pressure vessels (containing gas cylinders, the same below), pressure pipes, elevators, cranes, passenger ropeways, large recreational facilities and special motor vehicles in the field (factory). Boilers, pressure vessels (containing gas cylinders) and pressure pipes are special equipment of pressure bearing type. Elevators, lifts, passenger ropeways and large-scale recreational facilities are special mechanical and electrical equipment. The number of special equipment operators, the number of ten thousand of equipment deaths, the accident frequency and the number of special equipment safety supervision organization were selected as the analysis elements. The work of standardization is to unify repetitive things and concepts in social practice such as economy, technology, science and management by formulating, promulgating and implementing standards so as to achieve the best order and social benefits. In other words, standards are the summary and refinement of scientific, technological and empirical results, rules and regulations that need to be followed within the corresponding scope are determined after consultation and discussion among experts from all concerned. Heavy machinery industry standards include the standards of heavy machinery (metallurgical machinery), mining machinery, and material handling machinery (crane transport machinery) and large casting and forging.

By referring "China Heavy Machinery Industry Yearbook" and "China Price Statistics Yearbook", it can collect the statistical data of the safety condition of heavy machinery in each year and the affecting factors, and the chain index of price. The collected price index are deduced from each other and the fixed base price index for each year are obtained. Because each value in the statistical data is calculated according to the current price, the inflation situation in recent years is different and the present price and moisture of each year are also different. The period of higher inflation is much higher than that of lower inflation. In order to accurately reflect the growth rate of the main business income of heavy machinery, price index should be used to refer to each other [3]. Since the collected price index is chain index of price, it is the ratio of price level based on the previous year. It is expressed by formula as $\frac{a_1}{a_0}, \frac{a_2}{a_1}, \frac{a_3}{a_2}, \ldots \frac{a_n}{a_{n-1}}$. In order to make the data being compared, the chain index of price cannot meet the requirements. The base price index is the ratio of the level of the reporting period to that of a fixed base period, reflecting the development of prices over a longer period of time. It can be seen from the formula that the fixed-base price index is equal to the continuous product of the corresponding chain index of price, which is expressed by the formula (1) as follows[4-5].

$$\frac{a_n}{a_0} = \frac{a_1}{a_0} \times \frac{a_2}{a_1} \times \frac{a_3}{a_2} \times \cdots \times \frac{a_{n-1}}{a_{n-2}} \times \frac{a_n}{a_{n-1}} \tag{1}$$

According to the above conversion relations, the collected price index can be calculated mutually, and the fixed base price index for each year can be obtained. By dividing the current price index by the fixed base, the comparable price of main business income can be obtained. According to the national chain index of price index from 2009 to 2017, a fixed base price index of 100% in 2008 can be calculated. The data after processing are shown in Table 1.

Table 1. Data Processing Results of Safety Conditions and Indicators of Influencing Factors

Year	Death toll in ten thousand special equipment	Main business income (Billion Yuan)	Operators of special equipment (ten thousand people)	Standard quantity	Safety supervision organization	Accident frequency
2016	0.33	1324.42	1099.52	1175	4132	233
2015	0.36	1296.66	1047.64	1111	3799	257
2014	0.39	1290.81	963.79	1047	3573	283
2013	0.46	1172.12	829.79	1035	3236	227
2012	0.517	1037.62	706.09	955	3189	228
2011	0.595	889.91	657.6	951	3144	275
2010	0.67	710.38	562.23	935	3092	296
2009	0.76	577.78	520.02	768	3049	380
2008	0.82	493.51	380.92	719	3011	307

3. Analysis of the Correlation Degree

3.1. Dimensionless Processing of Raw Data

Dimensionless data processing is a unified transformation of the content of each index, so that the order of magnitude of each index is basically the same, in order to eliminate the impact of excessive disparity between different index dimensions and numerical standards, and avoid unequal "weight" situation [5-8]. In this paper, interval relativity is used to deal with the problem which is shown in formula (2).

$$X_i(k) = \frac{X_i(k) - \min\limits_k X(k)}{\max\limits_k X(k) - \min\limits_k X(k)} \tag{2}$$

Among them, k=1, 2... N; I = 0, 1, 2 ... M. It should satisfy $0 \le |X_i(k)| \le 1$.

The results of dimensionless processing are shown in Table 2. X_0 denotes the death toll in ten thousand special equipment, X_1 denotes the main business income, X_2 denotes the operators of special equipment, X_3 denotes the standard quantity, X_4 denotes the number of safety supervision organization, and X_5 denotes the accident frequency.

Table 2. Dimensionless data of safety conditions and influencing factors

X_0	X_1	X_2	X_3	X_4	X_5
0	1	1	1	1	0.039216
0.061224	0.966589	0.9278	0.859649	0.702944	0.196078
0.122449	0.959553	0.81112	0.719298	0.501338	0.366013
0.265306	0.816712	0.62465	0.692982	0.200714	0
0.381633	0.654833	0.4525	0.517544	0.158787	0.006536
0.540816	0.47707	0.38503	0.508772	0.118644	0.313725
0.693878	0.261007	0.25231	0.473684	0.072257	0.45098
0.877551	0.101423	0.19357	0.107456	0.033898	1
1	0	0	0	0	0.522876

3.2. Calculation of correlation degree

According to the grey system theory, the safety condition of heavy machinery is regarded as a grey system, and each influencing factor is an element in the system. The death toll in ten thousand special equipment was selected as the reference series, which is $X_0 = \{X_0(k) | k = 1,2,3,..., n\}$, and the number of influencing factors was listed as the comparative series, which is $X_i = \{X_i(k) | k = 1,2,3,..., n\}(i = 1,2,3,...m)$. Among them, n is the influencing factor. The correlation coefficient can be calculate between the influencing factors and the parent series according to formula (3) [9-11].

$$\zeta_i(k) = \frac{\min\limits_i \min\limits_k |X_0(k) - X_i(k)| + \sigma \max\limits_i \max\limits_k |X_0(k) - X_i(k)|}{|X_0(k) - X_i(k)| + \sigma \max\limits_i \max\limits_k |X_0(k) - X_i(k)|} \tag{3}$$

The formula $\min\limits_i \min\limits_k |X_0(k) - X_i(k)|$ is the minimum difference of two levels, $\max\limits_i \max\limits_k |X_0(k) - X_i(k)|$ is the maximum difference of two levels. The symbol of σ is the resolution coefficient, and its range of values is between 0 and 1, usually being 0.5. The calculation results are shown in Table 3.

Equal weight correlation degree is obtained according to formula (4):

$$r_i = \frac{1}{n} \sum_{k=1}^{n} \zeta_i(k) \tag{4}$$

The calculation results are as follows: r_1=0.481, r_2=0.514, r_3=0.540, r_4=0.512, r_5=0.699. The order of sub-series is main business income, operators of special equipment, standard quantity, number of safety supervision organization and accident frequency. The correlation order of x_0 is $r_5 > r_3 > r_2 > r_4 > r_1$, which shows that the sub-sequence $\{x_5\}$ has a better correlation with the parent sequence, $\{x_3\}$, $\{x_2\}$, $\{x_4\}$ takes the second place, and $\{x_1\}$ is the worst. That is to say, the accident frequency has the most significant impact on the death toll in ten thousand special equipment, followed by the standard number, special equipment operators and safety supervision agencies, and the main business income is the minimum.

Table 3. Relevant coefficient of various factors and safety conditions of heavy machinery

$\zeta_1(k)$	$\zeta_2(k)$	$\zeta_3(k)$	$\zeta_4(k)$	$\zeta_5(k)$
0.333	0.333	0.333	0.333	0.927
0.356	0.366	0.385	0.438	0.788
0.374	0.421	0.456	0.569	0.672
0.476	0.582	0.539	0.886	0.653
0.647	0.876	0.786	0.692	0.571
0.887	0.762	0.940	0.542	0.688
0.536	0.531	0.694	0.446	0.673
0.392	0.422	0.394	0.372	0.803
0.333	0.333	0.333	0.333	0.512

It should further straighten out the relationship between safety technical specifications and regulations and standards, and establish a benign interaction mechanism between them. It should continue to promote the integration and optimization of safety technical specifications and focus on solving the problems of excessive, detailed and complex safety technical specifications. Efforts should be made to promote the formulation of local legislation and standards, and to enhance the pertinence and operability of laws and regulations.

4. Conclusion

Through analysing the correlation degree, it is concluded that besides the factors of accident number, the number of relevant standards and the increase of the number of safety supervision institutions play an important positive role in the death toll in heavy machinery accidents. It should improve the dynamic supervision system, further clarify the responsibilities of safety supervision agencies at all levels, and should study and define the relationship between safety supervision and comprehensive administrative law enforcement, strengthen the training of safety supervision personnel, which is useful to improve the treatment of grass-roots safety supervision personnel, and reduce the responsibility risk of safety supervision personnel.

Because of the randomness of the collected statistical data and the unsatisfactory treatment of some statistical indicators, there will be some deviations in the calculation results. It is necessary to further improve the construction of information network, realize the interconnection, interoperability and sharing of data, and improve the reliability and accuracy of data.

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Acknowledgments
Project is supported by Research and Application of Common Technologies of National Quality Foundation (2017YFF0207200).