ISSN 2706-655X Vol.4, Issue 2: 1-8, DOI: 10.25236/IJFET.2022.040201

Verification of Safety Culture Elements Based on Quantitative Data Analysis

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Abstract: *This paper researched how to verify the 32 safety culture elements based on the research of the task group. Through the research of the verification literature of safety culture elements, five aspects of safety culture verification were obtained: safety culture elements induction, data analysis of safety culture quantitative measurement, extraction of safety culture elements in accident cases, extraction of safety culture elements in enterprise interviews and interpretation of safety culture elements. 53 safety culture elements were inducted by safety culture elements. Through analysing the quantitative data of safety culture, it is found that Element 24 had no significant difference among the two extreme groups, and the discrimination was low. In the accidents case, 28 elements of safety culture were extracted, so that 5 of the 32 elements were removed, and finally 27 safety culture elements were obtained.*

Keywords: *Safety Culture; Safety Culture Elements; Quantitative Measurement; Safety Culture Elements Induction*

1. Introduction

The discussion about safety culture elements has always been a hot topic in the theoretical circle of foreign countries, and it is also an area of debate about the study of safety culture. In the past 30 years, scholars have carried out a large number of researches on safety culture elements from different research angles, and promoted the development of safety culture in the coal industry, for example, food processing industry [1], manufacturing industry [2], construction industry [3], petrochemical industry [4], steel industry [5], transportation industry [6], health care industry [7], service industry [8] and other industries in different areas.

Because of the different research backgrounds of researchers and different angles of problems and so on, the safety cultural elements are different. After obtaining the safety cultural elements, it is worthy to verify whether the safety cultural elements are reasonable and effective. Therefore, this paper studied how to verify safety culture elements that have been obtained.

2. Analysis and Verification Methods for Safety Culture Elements

The literature of 71 safety culture elements was researched. Among them, 26 articles (36.6%) were certified through literature to verify the safety culture elements, and 19 articles (26.8%) were certified by using quantitative measurements of safety culture have been obtained to verify the safety culture elements, and 8 articles (11.3%) studied the actual situation of the enterprise to verify the safety culture elements, and 18 articles (25.4%) were certified by the use of brainstorming or group discussion to verify the safety culture elements has been obtained. On this basis, the safety culture elements verification methods chart was shown in Figure 1.

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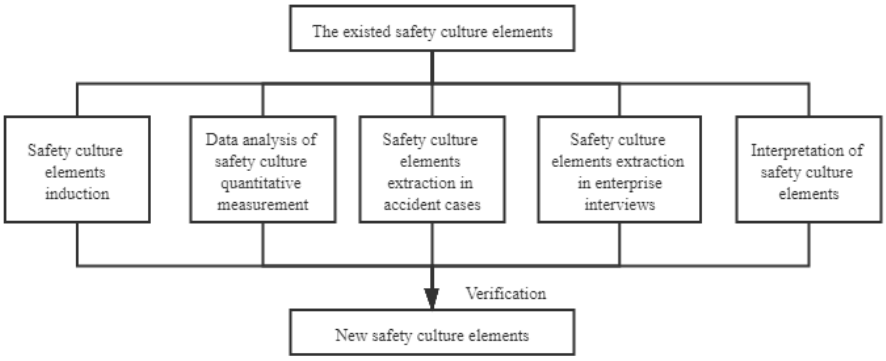

Figure 1: Verification methods of safety culture elements

3. Examples of Safety Culture Elements Validation

The research group modified the Stewart’s safety culture elements table 1 (contained 25 elements) [9] in Canada combined with China's actual situation to obtain 32 existing safety culture elements [10]. But it need to prove the comprehensiveness and validity of the 32 safety culture elements.

3.1 Safety Culture Elements Precipitation and Induction

60 articles about safety cult urge elements were counted. It was found that different scholars gave different names and different descriptions to the same safety culture element for different purposes. In order to find the safety culture elements that could embody the essential characteristics of safety culture and meet the definitions of safety culture, the author used information method to deal with the elements. Information precipitation method has two main steps: the first is the initial integration of elements and the second step is the classification of elements.

3.1.1 The Initial Integration of Safety Cultural Elements

Table 1: Safety culture merger process

No.	Factors / Authors	Safety commitment	Safety rules and regulations	Risk management	Safety Committee	Safety training	Safety responsibility
1	Smith et al[11]	Management commitment	Safety rules/regulations		employees		
2	Zohar[12]	Management's attitude towards safety		Risk of workplace	Safety Council status	The importance of safety training courses	
3	Glennon [13]		Health and safety legislation	Risk of workplace		The importance of safety training	
4	Brown, R. L. et al[14]			Risk	Safety Committee	Safety training	
...							
60	Tien-Ming Cheng et al[15]	Institutional and management safety commitment					

Different scholars have studied safety culture elements which have the same meaning and different names. For example, safety is firstly considered, safety priorities and they are both safety first. The management participates in safety and employees at all levels participate in safety, which all belong to safety participation. Safety equipment and maintenance are both for safe working conditions. The merger process of safety culture elements was shown as follows:

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3.1.2 Classification of Safety Culture Elements

By merging safety culture elements, the similar meaning and the same elements were removed, and then 53 safety culture elements were got in Table 2 below.

Table 2: The table of safety culture elements that were categorized and summarized

Safety commitment	Safety behavior	Safety attitude	Safety consciousness	Safety expectations	Safety satisfaction
Accident investigation	Implementation of safety rules and regulations	Promotion	Safety training	Safety awareness	Hazard identification
Safety responsibility	safety rules and regulations	Safety regulations	safety inspections	Safety integration	Contractor management
Safety management	Caring for injured workers	Organizational structure	Communication	Supporting environment	Safety incentives
Safety authorization	Emergency response	Accident prevention	Safety personnel status	Safety Information	Accident blame
Safety first	Safety assessment	Safety input	Safety Committee	Safety pressure	Safety resources
Safety participation	Line management department	Safety performance	Safety concerns	Safety conferences	The belief in safety
Continuous improvement	Colleagues influence	Safe after working hours	Safety knowledge	Management visibility	Safe work form
Safety tolerance	Safety advice	Safety confidence	Community safety	Safety inspection	

3.2 Data Analysis of Safety Culture Elements

The research group which the author belong to design a questionnaire with 32 safety culture elements. A total of 4470 employees of 82 enterprises were conducted a safety culture quantitative measurement. Then, analyze the data obtained and verify the safety of cultural elements, the analysis process is as follows.

3.2.1 Project Descriptive Statistics

The descriptive statistical analysis of data was carried out by using the standard deviation, kurtosis and skewness as statistics. The results were shown in Table 3.According to the research results, there were two basic conditions for the sample to obey the normal distribution: (1) The absolute value of the sample skewness was less than 3; (2) The absolute value of the sample kurtosis was less than 10. Only when skewness and kurtosis of the measurement project met the requirements, it was explained this item was valid.

Table 3: The results of safety culture elements analysis

	N	Std. Deviation	Kurtosis		Skewness	
	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Element 1	4470	1.4308	-.475	.043	-1.774	.085
Element 2	4470	1.0249	-.721	.043	-.278	.085
...						
Element 24	4470	1.76	1.138	1.542	.061	1.505
...						
Element 30	4470	.7962	-2.735	.043	5.546	.085
Element 31	4470	1.4276	.480	.043	-1.126	.085

Through the analysis, we could see that the standard deviation was basically between 0.5-1, which was in the ideal state. From the table, the absolute value of the skewness of the Element 24 was greater than 3, and the absolute value of kurtosis was greater than 10.

3.2.2 Extreme Group Test

Extreme group test: The average score of each element in the two extremes was calculated by selecting two extreme samples (27% of the total score) with the highest score and the lowest score. According to the independent sample T test, we assumed that H0: $\sigma_1^2 = \sigma_2^2$ (the variance was equal), and set the default value of the confidence interval percentage to 95% and the level of significance was 5%. Then the discrimination degree of the elements was judged. The criterion was shown in Table 4.

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Table 4: Extreme group test judgment criteria

Sig. (2-tailed)	Reject/Accept H0	Significant differences level	Discrimination
P＞0.05	Accept	No significant differences	Low
0.01＜P＜0.05	Reject	Significant differences	High
P＜0.01	Reject	Great significant differences	Greatly high

The statistics of each element in high-score and low-score groups were listed in Table 5, where the S.E. Mean referred to the standard error of mean.

Table 5: Extreme group statistics

	Group	N	Mean	Std. Deviation	S.E. Mean
Element 1	1.00	482	4.52	1.104	.050
	2.00	455	3.38	1.619	.076
Element 2	1.00	482	4.61	.704	.032
	2.00	455	3.54	1.065	.050
Element 3	1.00	482	4.74	.658	.030
	2.00	455	4.11	.956	.045
...					
Element 31	1.00	482	3.12	1.561	.071
	2.00	455	1.91	1.117	.052
Element 32	1.00	482	3.82	1.359	.062
	2.00	455	2.87	1.522	.071

After identifying the high-score and low-score groups, independent sample T tests were needed for each element. And the results were judged according to the criteria in Table 4. The extreme group test results were shown in Table 6.

Table 6: Extreme group test results

		Levene's Test for quality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Element 1	Equal variances assumed	219.277	.000	12.612	935	.000	1.136	.090	.959	1.313
	Equal variances not assumed			12.480	795.468	.000	1.136	.091	.957	1.315
...										
Element 23	Equal variances assumed	38.985	.000	7.815	935	.000	.488	.062	.366	.611
	Equal variances not assumed			7.839	932.942	.000	.488	.062	.366	.611
Element 24	Equal variances assumed	1.603	.206	1.167	935	.243	.091	.078	-.062	.243
	Equal variances not assumed			1.171	932.406	.242	.091	.077	-.061	.243
...										
Element 31	Equal variances assumed	125.822	.000	13.631	935	.000	1.215	.089	1.040	1.390
	Equal variances not assumed			13.759	872.322	.000	1.215	.088	1.041	1.388
Element 32	Equal variances assumed	2.714	.100	10.079	935	.000	.949	.094	.764	1.134
	Equal variances not assumed			10.046	908.627	.000	.949	.094	.764	1.134

From Table 6, it could be seen that only Element 24 of the extreme group test results had a significant difference of P> 0.05, indicating that the Element 24 had no significant difference in the two extremes, and the discrimination was low. From the project descriptive statistics test and the extreme group test results, the mean value of the Element 24 was obviously low, and the significant difference between the high-score and low-score groups was not obvious. So the Element 24 was deleted, and then the 31 elements were checked in extreme group test.

After deleting the Element 24, the significance rates of the two-sided tests of the remaining 31 elements were less than 0.05, which was a significant difference. Except for the Element 25, the significance rates of the two-sided tests of the other elements were less than 0.01, and the significant differences were obvious. In combination with the descriptive statistic test of Table 3, it was clear that the mean value of Element 24 was significantly lower than that of other elements, and there was no significant difference between the high-score and low-score groups. The results were shown in Table 7.

Table 7: Results of the second extreme group test

		Levene's Test for quality of Variances		T-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
Element 1	Equal variances assumed	259.830	.000	13.025	873	.000	1.177	.090	1.000	1.355
	Equal variances not assumed			13.044	743.229	.000	1.177	.090	1.000	1.354
......										
Element 23	Equal variances assumed	31.247	.000	7.286	873	.000	.476	.065	.348	.605
	Equal variances not assumed			7.284	863.839	.000	.476	.065	.348	.605
Element 25	Equal variances assumed	.893	.345	2.019	873	.044	.109	.054	.003	.215
	Equal variances not assumed			2.020	860.027	.044	.109	.054	.003	.214
...										
Element 31	Equal variances assumed	135.496	.000	13.772	873	.000	1.265	.092	1.085	1.446
	Equal variances not assumed			13.756	777.517	.000	1.265	.092	1.085	1.446
Element 32	Equal variances assumed	3.693	.055	9.946	873	.000	.969	.097	.778	1.161
	Equal variances not assumed			9.950	861.189	.000	.969	.097	.778	1.160

3.2.3 Reliability Test

Reliability test means that the reliability of the whole questionnaire is computed by calculating the Cronbach's alpha. According to the Reliability test judgment standard, when alpha is less than 0.6, the reliability level is quite low and the scale acceptability is unacceptable. And when alpha is greater than 0.6, the reliability level is acceptable but only for reference [16].

The author used SPSS to test the reliability of 1602 valid samples (randomly selected). The reliability coefficient of the existing element table was 0.59 less than 0.6, which indicated that the reliability level of the existing element table was low. The Element 24 in the above was deleted due to both the mean and extreme group test unsatisfied results. Therefore, it is necessary to carry out the reliability test on the new element table after deletion. The sample quantity of the reliability test was still 1602. The reliability coefficient obtained by this test was 0.627, which was higher than before. In addition, the author also tested the reliability of the new element table after deleting other elements. The results were shown in Table 8.

Table 8: Reliability test results

Elements	Cronbach's Alpha if Item Deleted	Elements	Cronbach's Alpha if Item Deleted	Elements	Cronbach's Alpha if Item Deleted
aElement 1	.616	Element 12	.594	Element 23	.615
Element 2	.593	Element 13	.613	Element 25	.625
Element 3	.611	Element 14	.608	Element 26	.594
Element 4	.614	Element 15	.625	Element 27	.593
Element 5	.613	Element 16	.617	Element 28	.608
Element 6	.606	Element 17	.608	Element 29	.623
Element 7	.629	Element 18	.607	Element 30	.601
Element 8	.594	Element 19	.616	Element 31	.611
Element 9	.610	Element 20	.614	Element 32	.622
Element 10	.608	Element 21	.615		
Element 11	.630	Element 22	.616		

As could be seen from Table 8, for the new table after the deletion of Element 7 and Element 11, the element reliability increased slightly, but not significantly. The reliability of other elements in the table was decreased, so it could be said that the new element table was credible.

3.2.4 Comprehensive Analysis of Test Results

According to the results of the test, it could be seen that the mean value of Element 24 was significantly lower than that of the other elements, and the score of the element in the two extremes was not significantly different, so the Element 24 should be deleted. The reliability of the elements table before and after deletion was calculated respectively. It was found that the reliability of the elements table was obviously improved after deleting the Element 24, and further proved that Element 24 was unreasonable and should be deleted.

In summary, Element 24 of the safety culture elements should be deleted.

3.3 Accident Case Extraction of Safety Culture Elements

748 coal mine accidents have been counted. The safety culture elements extracted from them were shown in Table 9 below.The number of times in the table indicated the number of occurrences of poor safety culture elements in the accidents, and an accident was counted once.

Table 9: Summary of safety culture elements extracted from the accident

NO.	Safety Culture Elements	Times of occurance	NO.	Safety Culture Elements	Times of occurance
1	Safety is determined by safety consciousness	694	15	Work of the safety department	91
2	The importance of safety	618	16	The type of safety inspection	89
3	Safety training needs	533	17	The role of the safety organization	74
4	The role of safety regulations	531	18	Line management responsibility for safety	58
5	The main responsibility for safety	378	19	The formation of safety values	54
6	The implementation of the safety system	285	20	Emergency capability	34
7	The belief that all accidents can be prevented	260	21	The formation of safety rules	29
8	Safety integrate into management	230	22	The relationship between safety performance and human resources	6
9	Degree of leadership responsibility	223	23	The treatment of safety performance	5
10	The role of the management system	194	24	The type of accident investigation	4
11	Employee involvement	151	25	Safety management of subsidiaries and contract units	4
12	Awareness of safety inputs	126	26	The role of the safety department	2
13	Safety creates economic benefits	113	27	The quality of the safety conference	1
14	Facility satisfaction	102	28	Caring for injured workers	1

3.4 Extraction of Safety Culture Elements in Interviews

After interviews with three large state-owned enterprises' management personnel and front-line staves in China, a total of 30 people, we got the following key safety culture elements:

(1) Effective and appropriate safety management systems were needed to eliminate safety work and the promotion of correct attitudes and behavioral barriers in the organization;

(2) Safe leadership and visible management of safety and health commitments were needed, which required the whole organization to feel "clearly from the priority and resources to give safety";

(3) Employee participation and a positive attitude towards safety and health were needed;

(4) Organizational learning and continuous improvement were needed, and accidents and failures were seen as valuable lessons and the opportunity to improve action.

ISSN 2706-655X Vol.4, Issue 2: 1-8, DOI: 10.25236/IJFET.2022.040201

3.5 Comprehensive Analysis of Safety Culture Elements

After above contents of this study were verified and 27 new safety culture elements were obtained, as shown in Table 10 below:

Table 10: List of new safety culture elements

The importance of safety	Awareness of safety inputs	Safety training needs	The type of accident investigation
The belief that all accidents can be prevented	The role of safety regulations	Line management responsibility for safety	The type of safety inspection
Safety creates economic benefits	The formation of safety values	The role of the management system	Caring for injured workers
Safety integrate into management	Degree of responsibility of leadership	The quality of the safety conference	Facility satisfaction
Safety is determined by safety consciousness	The role of the safety department	The formation of safety rules	The relationship between safety performance and human resources
The main responsibility for safety	Employee involvement	The implementation of the safety system	Safety management of subsidiaries and contract units
The role of the safety organization	The role of the safety department	Emergency capability	

4. Conclusion

To sum up, we got the following conclusions:

(1) Through the study of the source of safety culture elements, five aspects of safety culture verification were obtained: safety culture elements induction, data analysis of safety culture quantitative measurement, extraction of safety culture elements in accident cases, extraction of safety culture elements in enterprise interviews and interpretation of safety culture elements.

(2) Examples verified safety culture elements. And through the verification of five aspects of safety culture elements, it confirmed that 5 of the 32 elements of safety culture were removed, and finally 27 safety culture elements were obtained.

Acknowledgements

This paper is supported by College Students' Innovation Training Program (project number: 202112027) and the Postgraduate Research and Innovation Ability Improvement Project (project number: 2021YJSAQ10).

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ISSN 2706-655X Vol.4, Issue 2: 1-8, DOI: 10.25236/IJFET.2022.040201

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