Empirical study in assessment of safety climate in construction site

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Abstract: **With the rate of safety accidents during the engineering construction becoming higher and higher, more and more attention was paid on engineering safety. To better cognize the present safety situation of engineering construction without which prevention are hard to develop, this paper developed 2 surveys which aims at evaluating the present safety situation of a series of construction dominated by urban construction bureau of Dong'guan city in Guangdong province. Based on so many existing papers, safety climate is the most important impaction of safety accidents, furthermore, safety altitude reflect safety climate to a great extent, thus the first survey is developed to testify the conclusion. Based on the conclusion, another survey is developed to evaluate safety situation in Dong'guan city.**

Keywords: safety climate, construction, safety accidents

I. INTRODUCTION

Viewing from all over the world, the occurrence rate of the safety accidents during the engineering construction has always been ranked at the top in all the industries. And the foreign statistical data shows: in UK, the direct and indirect losses caused by the construction safety accidents can account for as high as 3%~6%, which accounts for 7.9% of its total cost, and more seriously, 8.5% in Hong Kong. Though no public statistical data has been released in the mainland, viewing from some extra serious accidents occurring in recent years, the situation is no optimistic.

The incentive of the safety accidents can be reduced to the "unsafe state of the objects" and the "unsafe behavior of the human". In recent years, the research aimed at safety accidents is not only focused on such measures as eliminating the unsafe state of the objects, etc. but also views these human factors including the consciousness of the organization and the management, the worker's behavior, etc. as an import cause of the safety accidents. These researches have been specially concentrated upon the discussion on the enterprise's safety culture, and also have a view of point that it needs to carry out the work first from the improving the safety culture of the construction enterprise, even the whole construction industry, to control the unsafe behavior of human. Despite some viewpoints have been put forward that safety culture represents the intention of the management, however, in effect, the formation of safety culture mechanism is very complicated, and is difficult to measure and evaluate. Therefore, the concept of "safety atmosphere" is put forward by the foreign scholars before we try to the quantificational research on the safety culture.

Table 1 Definition of safety climate

Author	Year	Definition
Zohar	1980	The cognition towards risky working environment shared by employees of an organization.
Brown and Holmes[1]	1986	A set of perception or belief on a certain entity by an individual or a group.
Cooper and Philips[2]	1994	Workers' common perception and belief on the safety of their workplace.
Williamson[3]	1997	Describing the concept of the safety ethics of an organization or a workplace which is reflected in the employees' belief in safety.
Cox and Cheyne[4]	2000	Climate is the temporary manifestation of culture which is shown through the cognition shared within a group in a certain time.

Sivla[5]	2004	Organizational atmosphere and safety climate refer to a shared view on the organization's value view, standard, practice and norms which can be observed and measured.
Chen[6]	2005	Safety climate refers to the sum total of opinions on the safety by all employees of an organization.

As we can conclude from the researches above, the safety climate is viewed as a more concrete, more microcosmic, and capable of being measured concept, which is the current, superficial features of safety culture, relating to the attitude and feeling of the employees. Consequently, the safety culture of the enterprise can be reflected by the measuring and evaluation of the safety atmosphere of the enterprise.

To better research the methods to reduce the possibility of safety accidents, this essay progress two surveys focus on safety climate. The first survey gives out a hypothesis that safety attitude play an important role in influencing safety attitude based on literature review, as following, proving it through questionnaire analysis. In the second survey, the same method of questionnaire analysis in the first survey has been adopted to analyze safety altitude of PPE(personal protective equipment) from workers.

II. SURVEY I

In this survey, after the given out hypothesis based on literature review, most part of workforce in the construction sites in Dong'guan city is choosen as questionnaire survey respondents, and by the methods of secret filling, the feelings about the safety climate at construction site from the workers is measured, to further reflect the safety culture construction state of the enterprise. The research process mainly includes the questionnaire design-data collection-questionnaire analysis on the results.

A. Literature review

The purpose of this section is to review the safety climate literature, paying particular attention to the results of studies that have identified influences on, and the influences of safety climate. In total, 31 studies were identified in the literature and are reviewed in this section. The majority of these studies were conducted in high hazard industrial sectors, including transport, power generation, offshore oil and gas production, manufacturing, and construction. The results are presented thematically, under managerial factors, supervisory factors, workforce factors, and other system factors.

In factors of workforce,Cheyne, et al.[7] found that the individual responsibility of workforce members played an important role in the success of safety management influence on safety activities. In this multi-sample analysis of workforce perceptions within a multinational manufacturing company, mediating factors included personal involvement, communication and hazards. Cheyne et al.[8] investigated the role of workers' personal responsibility further in a study of multiple organizations and concluded that personal responsibility for safety is complementary to, and not a replacement of, good safety training.

In an attempt to shift focus back to group perceptions of safety climate rather than analyses conducted at the individual level, Zohar**Error! Bookmark not defined.** found support the hypothesis that safety climate is a group-level construct. He found that group perceptions of supervisor action and supervisor expectation were significant predictors of minor injuries within workgroups for up to five months after the perceptions were collected.

Based on the literature above, among all the factors relates to safety climate, this paper gives out a hypothesis that safety altitude closely relates to safety climate and play a significant part. The following parts show the method and results.

B. Methodology

1) Questionnaire design

The questionnaire has two parts: individual basic information part and questionnaire main body part. The personal information part includes gender, age, education level, work experience and other information. The main part mostly bases on The Loughborough University Safety Climate Assessment Toolkit and User Guide – LSCAT. This Guide is a measuring tool developed by Loughborough University, British health and Safety Nevada and some well-known enterprise cooperation, and it's suitable for offshore oil enterprise safety climate measurement. It includes a total of 43

questions in 10 dimensions. On that basis, and in order to ensure that the questionnaire content are more suitable for our country construction enterprise safety climate measurement, design of safety atmosphere questionnaire. After modification and classification, the questionnaire with seven dimensions and a total of 33 questions are finally determined.

The distribution of questions contained in all dimensions is shown in chart 2, each question is based on Likert 5 point scale score thoughts:1. Strongly disagree;2. Disagree;3. Neither agree nor disagree;4. Agree;5. Strongly agree.

The specific answers are designed, and 5-1 points are given according to the agree and disagree level. Reverse questions (for example the 10th question "sometimes in order to implement the progress, illegal operation is necessary") are respectively given 1-5 points. In the questionnaire, question 10, 19, 25, 27, 30, 31, 33, 37, 38, 41 are reverse topic. The higher score means better safety climate, otherwise the safety climate is worse.

a) Data collection

This research conducted questionnaire survey in several typical engineering construction site in Dong'guan city, included given out of 200 pieces of questionnaire and reclaim of 164 pieces, of which the rate of reclaim is 82%. Next, data of Questionnaire reclaimed are put into SPSS(Statistical Package for the Social Sciences) software, and screen is made to delete the invalid questionnaire according to the rules as following:1. There're more than 3 questions haven't been answered; Answers followed certain rules; Multiple choices are exist for one question;Finally, 140 pieces of questionnaire are identified as valid, valid rate of which is 85%.

2) Questionnaire analysis

a) Extraction of factors of safety climate

In social scientific research field, principal component analysis (PCA) is frequently used to achieve variable decrement and exploratory factor analysis, and also testify the structure validity of this questionnaire. PCA is able to develop new index by linear combination of each variable. And the new index could extract information as much as possible. When the first linear combination is no long able to extract more information, then the second linear combination was taken into

account for fast extraction, till the difference between extractive information and original variable is fairly low. This paper makes a PCA of each dimension of the questionnaire, aims at synthetically refining the questions in each dimension through ideology of principal component.

Table 2 Principle component analytical result

Name of dimension	Times of analysis	Number of extracted principle component	Explanatory rate of accumulated variance	Analytical result of component matrix	
		First analytical result		First time	Second time
Management commitment	1	1	95.713%	Reasonable for load capacity of each variable factor is greater than 0.9.	
System and standard	2	1	73.689%	Delete for load capacity of question No.10 is extremely low.	Reasonable for load capacity of each variable factor is greater than 0.9.
Behavior and influence of workforce	1	1	91.785%	Reasonable for load capacity of each variable factor is greater than 0.9.	
Safety communication	2	1	63.326%	Delete for load capacity of question No.21 is extremely low.	Reasonable for load capacity of each variable factor is greater than 0.4.
Safety involvement	2	1	65.525%	Delete for load capacity of question No.25 is extremely low	Reasonable for load capacity of each variable factor is greater than 0.9.
Safety environme	2	2	74.523%	Delete for load capacity of second	Reasonable for load capacity of

						Dimension 3：Behavior and Influence of workforce	0.970
nt				principle component is greater than 0.4.	each variable for is greater than 0.4.	Dimension 4：Safety communication	0.635
Cognition of safety risk	2	2	76.456%	Delete for load capacity of both two principle component are greater than 0.4.	Reasonable for load capacity of each variable for is greater than 0.4.	Dimension 5：Safety involvement	0.514
						Dimension 6：Safety environment	0.835
						Dimension 7：Risk cognition of safety	0.766

c) The status evaluation of safety climate

b) Examination of reliability and validity of scale

This paper makes a examination of reliability and validity of the new formal scale after striking out unsatisfactory questions via PCA.

Reliability, it indicates the consistency of repeat measurement results for one same subject by same method. Refer to reliability and validity of survey, there is a reliability test requirement usually. The major methodologies of reliability analysis are 4 ways: 1. Test-retest reliability method; 2. Equivalent-form method; 3. Cronbach's alpha method. Among them, "Cronbach's Alpha" is from Likert scale which is commonly used reliability testing, and it is also the methodology employed in this research. The computational formula is:

$$\alpha = \frac{k}{k-1}\left(1 - \sum \frac{S_i^2}{S_T^2}\right)$$

(1)

Among them, k is the amount of topic in the survey; S_i^2 is the variance of score of topic i; S_T^2 is the variance of all topics' total score.

α represents the level of consistency of the scale, and it is between 0 and 1. A scale with a higher reliability indicates better stability. α's calculation results of safety climate survey designed by this research is shown in the figure 8 below, the α of total scale is 0.968, and it explains that the total scale has a high level of consistency, every dimension of α is between 0.514 to 0.989, except the fifth dimension is relatively low, and the rest 6 dimensions all have a very high α, all in all the reliability of scale is acceptable.

Table3 Coefficient *a* of Overall scale and each dimension

	Coefficient *a*
Overall scale	0.968
Dimension 1：Management commitment	0.989
Dimension 2：System and standard	0.968

According to the result of survey dimension analysis, and the scale built up by 7 dimensions including management commitment etc can show worker's feeling about safety climate comprehensively, every dimension is calculate by the equation:

$$S_i = \frac{1}{n_i} \sum_j c_{ij}$$

（2）

Si is the score of dimension I, and n_i is the topic of dimension I, c_{ij} is topic j's score of dimension i.
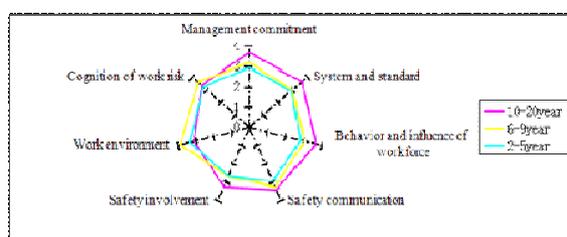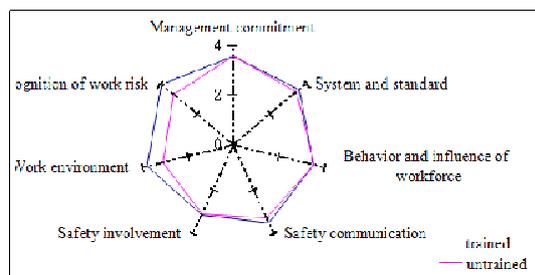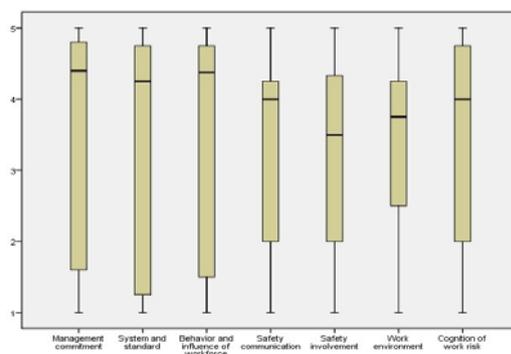
3) Result

The safety climate evaluation of enterprise's construction site includes comprehensive analysis of safety climate and characteristics differences between groups.

The result of statistic analysis indicates:

1) From the figures above, it shows: the worker's feeling of safety climate is fair enough, and it shows that every dimension of safety climate got positive feedbacks from workers, because average score of every dimension is bigger than 3, and from the box-plot, the distribution of every dimension's score is a left skew (median is bigger than average), and it also illustrates that most workers' feeling about safety climate is positive, and the average level is even higher.

2) This construction site does not have obvious lack of safety culture problem. Especially, it shows that the enterprise has a well comprehensive safety standard and regulation, co-workers usually do mutual supervision and remind about safety issues. Paying more attention on safety issues brings high level of safety awareness. (standards, regulations, behavior and influence of co-workers, and risky awareness of jobs etc are 3 dimension which got average scores equal or higher than 3.5)

3) However, the score of workers' feeling about management commitment is the highest, while the standard deviation is largest, and the scores distribution of this dimension in from box-plot indicates that the feelings of this aspect have significant differences among workers. At the same time, the overall feeling of working environment is poor, it will cause a generally low awareness of importance of safety communication and level of safety participation, therefore, and the construction site still needs improvement in these aspects, and takes more motivation action to encourage workers to report all kinds of incidence, and accepts reasonable advise from workers about safety issues more aggressively.

III. SURVEY Ⅱ

PPE, an important safety tool in construction, is directly related to the safe operation of workers. Therefore, this paper will take PPE as an example and compile a questionnaire on construction workers' safety attitude towards PPE according to the characteristics of construction workers and their use of PPE on the base of 3-dimension framework of attitude raised by Rosenberg and Hovland. The following part will analyze and discuss the credibility and validity of scale and the classification and judgment method within this paper in the hope of enriching the study perspectives on construction workers' safety attitude in the field of construction safety study and providing more standardized measurement tools for studying the construction workers' safety attitude in China.

A. Methodology

The same method of the first survey is adopted to develop a questionnaire, and attitude scaling and attitude judgment are worked out by the following methods.

This study is using Twostep Cluster method to analyze attitude scaling. Twostep Cluster is capable to find out "Optimal" number of clusters automaticity. The analysis result:

Table4 Cluster distribution

		N	amount %
Cluster	1	120	69.4%
	2	48	27.7%
	3	5	2.9%
	group	173	100.0%
Amount		173	100.0%

	zFCognition		zFAffection		zFBehaviour	
	Mean value	Standard deviation	Mean value	Standard deviation	Mean value	Standard deviation
1	-.3599	.422308	-.1197	.25868	-.1006	.2395
2	1.2104	.474980	.5158	.26351	.4760	.37962
3	-2.9803	1.57168	-2.0793	1.16970	-2.1552	.31239
group	.00000	1.00000	.0000	.55410	.0000	.53542

As table 4, "the distribution of clusters" scale gives 3 kinds of observed frequency of finalized clusters, and the first category has the most observed numbers, and it is followed by the second and third categories.

Cluster abstract document:

Table 5 Barycenter

The table 11 is center of mass form, which shows statistic information about the average and variance of continuous variable. According to the observation, the cognition, emotion and behavior of the second category are the biggest; the first category come the next, the third category is the smallest. As this shows, all these 3 categories have outstanding characters, and distinguish them well. We can name the second category "Good Attitude", the first category is "Normal Attitude", the third category is named as "Bad Attitude".

a) Attitude Judgment

Based on Discriminate Analysis, this survey can make attitude judgment for unknown attitude level of individual case. Discriminate Analysis is one of most important sample's category discriminate methods among multivariate statistical analysis. It is a statistic method based on how multi factors (index) influence objects, and distinguish objects. Discriminate Analysis is every effective when building up grouping prediction model for every individual case. This process is based on the linear combination which provides the best discrimination of each group, and produce one or more than one discriminate function, this function is able to predict the status of new grouping case of unknown category.

In this chapter, it picks the known attitude level of measurement sample illustrate 153 as the sample of building up discriminate function, it assumes that other 20 examples are unknown categories, and it hopes that attitude level classification can be done by Discriminate Analysis.

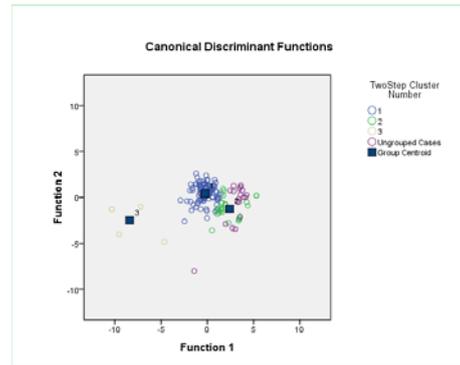a. Canonical Discriminant Functions

Figure.1 Canonical Discriminant Functions

Figure.1 shows the scatter gram made through computing all coordinates on two-dimensional plane and adding the coordinates of the mass center of 3 groups by using the two characteristic discriminant functions. It can visually show the results of the categorization using characteristic discriminant functions. Judging from this, we can say that 3 groups can be distinguished clearly.

Figure 2 Classification Results

Classification Results[a]

		TwoStep Cluster Number	Predicted Group Membership			Total
			1	2	3	
Original	Count	1	113	5	0	118
		2	2	28	0	30
		3	0	0	5	5
		Ungrouped cases	1	19	0	20
	%	1	95.8	4.2	.0	100.0
		2	6.7	93.3	.0	100.0
		3	.0	.0	100.0	100.0
		Ungrouped cases	5.0	95.0	.0	100.0

a. 95.4% of original grouped cases correctly classified.

The categorization result displayed in Table 16 is the statistical information predicted using the characteristic discriminant functions. Take the first line for illustration. In initial data there are 118 individual cases falling in the first group. After the judgment of characteristic discriminant functions, 110 cases are placed in the first group (proving correct prediction), 7 cases are placed in the second group, and 1 case is placed in the third group. The other data has similar meaning to this one.

Finally, 94.8% (145/153) of the initial observation cases have been categorized correctly. In the 20 cases of the attitude-unknown category have been divided into three groups, and the ratio of first group: second group: third group is 1: 18: 1. It means that in the 20 cases of the

attitude-unknown category, 18 have good attitude, 1 with bad attitude and 1 with normal attitude.

3.2.3 Result

The result shows that the development of the attitude of construction workers to PPE safety questionnaire bases on the application of psychology test compilation principle and technology. This questionnaire has three assessment scales: cognitive, emotional and behavioral intention. Through the factor analysis, it is found out that the cognitive section is constituted by "cognitive factor"; Emotional section consist of "subjective attitude factor" and "emotional experience factor; Behavior tendency component table by "behavior experience factor" and "behavior control factor". By using the Two-step cluster analysis, the test sample of the attitude to the safety of the PPE is divided into three levels, "good attitude", "general attitude" and "bad attitude".

IV. DISCUSSION

Through the process of the two surveys above, we are able to develop a meaningful questionnaire based on reliability and validity analysis. Since the importance of safety attitude in the relationship with safety climate has been testified, more attention will be paid to safety attitude to better solute the problems in safety accidents.

Particularly for the second survey, the questionnaire is used to find out the attitude of construction workers to the safety of the PPE, Both results show that it's reliable and effective upon testing. Meanwhile through the clustering and discriminant analysis, it provides a new way to evaluate attitude and the attitude classification accuracy reaches 94.8%. That is, using the discriminant analysis, and studying on the case of the unknown categories, the attitude level can be defined; for those samples with known attitude level, this research can be used to verify its forecast classification. However, the construction workers PPE safety attitude measurement is a qualitative evaluation, the results of quantitative evaluation on the attitude measurement still need further research.

In the process of questionnaire developing, an attempt is made to combine psychology knowledge to start theoretical construction on workers safety attitude on all dimensions, it contributes to the further psychology research on the construction workers' safety attitude, and helps other researchers put forward problems. This paper studies the classification and definition in this paper on the construction workers' safety attitude can be used to evaluate the site construction personnel occupational safety attitude. Safety attitude affect the professional quality and the improvement of skills of construction enterprise employees, and influence their safety operation behavior. Therefore, this research helps to improve the safety awareness of workers, reduce the incidence of accident in construction industry. This research mainly aims at the measurement concerning about safety attitude, but according to the research thought, it can be extended to the research of construction workers' attitude to general safety norms or rules and regulations level definition, and it plays a catalytic role on the further study of the construction industry safety attitude measurement. According to the results of construction worker safety attitude measurement, we can purposefully culture and change the construction workers' safety attitudes with level lower, which help reduce the incidence of construction industry safety accidents.

REFERENCE

[1]. BROWN , R.L. , HOLMES,H.THE USE OF A FACTOR——ANALYTIC PROCEDURE FOR ASSESSING THE VALIDITY OF AN EMPLOYEE SAFETY CLIMATE MODEL.ACCIDENT ANALYSIS AND PREVENTION.1986，18(6):455 — 470.

[2]. Cooper M D and Phillips R A.Exploratory analysis of the safety climate and Safety behavior relationships.Journal of Safety Research，2004，35:497 — 512.

[3]. Williamson AM，Feyer AM，Cairns D，et al.The development of a measure of Safety climate:the role of safety Perceptions and attitudes.Safety Science.1997，25:15 — 27.

[4]. Cox S J，and Cheyne A J T.Assessing safety culture in offshore environment.Safety Science.2000，34:111 — 129.

[5]. Silva S，Lima M L，and Baptista C.OSCI:an organizational and safety climate inventory.Safety Science.2004，42:205 — 220.

[6].1 Chen Y，Fang D P，Lan R X，et al.The Relationship between safety climate and Personal characteristics.the Triennial Conference CIB W99 Rethinking and Revitalizing Construction Safety，Health，Environment and Quality，17 — 20Mya2005，Port Elizabeth，South Africa

[7]. Cheyne, A., Cox, S., Oliver, A., & Tomas, J. M. (1998). Modelling safety climate in the prediction of levels of safety activity. Work and Stress, 12, 255-271.

[8]. Cheyne, A., Cox, S., Oliver, A., & Tomas, J. M. (1998). Modelling safety climate in the prediction of levels of safety activity. Work and Stress, 12, 255-271.