화학공장의 안전문화 평가와 영향변수

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Safety Climate Assessment and Its Relation to Reliability in Chemical Plants

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INTRODUCTION

Safety climate has been recently recognized as a fundamental and ultimate solution for improving workplace safety in various industries including manufacturing industries such as chemical plants. Lord Cullen[2] emphasized that, during the Piper Alpha inquiry, it is essential to create a corporate atmosphere or culture in which safety is understood to be and is accepted as, the number one priority. Fennell[3] stated that, following the Kings Cross fire, a cultural change in management is required throughout the organization. Petersen[4] demonstrated that culture is to a large degree behind human-caused catastrophes. Zebroski[5] found eleven attributes which have had medium to large degrees of commonality in the basis for the TMI-2, Chernobyl, Challenger, and Bhopal events. There have been some movements to improve safety culture and climate among industries as well as government agencies in Korea. But the safety climate study has not been done in Korean manufacturing industries. There has been a general agreement to create a safety climate in Korean manufacturing industries, but few validated tools exist to measure important elements of a safety climate. We explore the validity of HSE[6] instruments in Korean industry to measure safety climate. Furthermore, factors that may influence the workers' safety culture and climate investigated.

METHODS

The survey was adopted from HSE. The constructs and items used in this study can be found in Core Safety Climate Item Set Appendix part of HSE report[6]. Underlying constructs (Management commitment to safety (M1), Merits of the Health and Safety (H&S) procedures, instructions, and rules (M2), Accidents and Near-misses (M3), Training and Competence (W1), Job security and Satisfaction (W2), Pressure for production (W3), Communications (W4), Perceptions of personal involvement in H&S (W5), Perceptions of organizational & management to H&S (W6), Rule breaking (W7), Workforce view on state of safety & culture (W8)) and associated hypotheses are discussed below. Constructs M1, M2, and M3 are the managerial role in promoting safety and W1 through W8 are the role of non-managerial workers.
Table 1 contains a summary of the hypotheses tested.

Table 1. Hypothesis

H1: Safety climate at the plant differ by size (number of employees)
H2: Favorable safety climate at plant are associated with lower number of reported accident

Questionnaire and Sample

Safety representatives from each company were asked to answer the statements using a five five-point Likert-scale ranging from 'fully agree' to 'fully disagree.' Some of the items in the questionnaire were expressed negatively and these items were reversed as necessary so that a low score equals a positive orientation toward safety. Six hundred forty two plants selected for this study include petrochemical, chemical, electric, and steel industries, which may have potential major accidents such as fire, explosion, and toxic release. Among 642 targeted plants for the questionnaire survey, 195 plants (30.4%) agreed to participate in this study.

Assessment of Measurement Tool

Prior to data analysis, internal-scale reliability was assessed to ensure the consistency of the items in each construct. Internal-scale reliability is applied to groups of items that are thought to measure different aspects of the same concept[7,8]. It is important that a group of items clearly focus on the constructs and the accepted level of the result (Cronbach'α) is approximately 0.7[8]. Measures of internal-scale reliability range from 0.61 to 0.95. The Cronbach's alpha obtained for each construct is listed in main diagonal of Table 2. Further analysis was not carried out for the construct, 'Pressure for production', with α of 0.61. Rest of the constructs showed satisfying Cronbach alpha. Correlations (Pearson's r) among managerial and non- managerial workers are presented in Table 2 and Table 3 respectively.

Table 2. Correlations among managerial workers

Factors	M1	M2	M3
M 1	0.88		
M 2	0.38	0.69	
M 3	0.62	0.59	0.72

All correlations significant at 0.01 level
Cronbach'α shown in main diagonal

Table 3. Correlations among non-managerial workers

Factors	W1	W2	W3	W4	W5	W6	W7	W8
W 1	0.86							
W 2	0.71	0.70						
W 3	0.42	0.65	0.61					
W 4	0.73	0.71	0.48	0.93				
W 5	0.63	0.59	0.34	0.70	0.83			
W 6	0.64	0.78	0.63	0.81	0.64	0.87		
W 7	0.41	0.45	0.68	0.32	0.31	0.39	0.95	
W 8	0.63	0.60	0.41	0.69	0.64	0.68	0.29	0.67

All correlations significant at 0.01 level
Cronbach'α shown in main diagonal

RESULTS and DISCUSSION

Descriptive findings

Out of 195 responded plant safety representatives, seventy three (37.4%) were working for 'more than 1,000 employees', fifty three (27.2%) for 'between 100 and 499 employees', and twenty nine (14.9%) were working for '30 to 99 employees' size plant. The responses are presented in Table 4. Sixty eight percent (n=133) of the response were from large plants of more than 100 employees. The responses by length of employment of the safety representatives are listed in Table 5. Representative who worked for more than four years (159; 86.5%) responded higher. Number of injury per 1000 employee in recent 12 months by age and length of employment is presented in Table 6 and Table 7, respectively. Most frequent injury was reported in 26 to 35 years old group and "Less than 2 years of employment group."

Level of Safety Climate

Frequency analysis was conducted to identify the level of safety climate in plant level and individual level. Individual factors that comprise the safety climate score were summarized in Table 8. Each factor score ranged from a minimum 1 and a maximum 5. Variability on all factors across managers and workers are listed in Table 8. In the survey to managers, the mean value ranged from 1.41 to 2.08 which imply high level of safety climate. Particularly, M1 is the most consistently well rated factor (as determined by the mean value). Workers' responses showed a little more negative and recorded that W4 is the highest level of safety climate (mean value of 1.68) and W3, W7, and W2 are relatively low rated factors.

Table 4. Response by plant size (number of employees)

Length of employment	No. of response (%)
Less than 1 year	9 (4.9)
1 ~ 3 years	16 (8.7)
4 ~ 10 years	68 (37.0)
More than 10 years	91 (49.5)
Total	184 (100)

Table 5. Response by length of employment

Plant Size	No. of response (%)
Less than 30	18(9.2)
30 ~ 99	29(14.9)
100 ~ 499	53(27.2)
500 ~ 999	7(3.6)
More than 1,000	73(37.4)
No response	15(7.7)
Total	195(100)

Table 6. Injury per 1000 in recent 12 months by age group

Age	< 25	26-35	36-45	≥ 46	Total
ARI	1.1	14.9	14.5	15.1	14.3
NARI	1.1	4.2	2.5	1.4	3.0
MI	7.9	6.0	2.7	1.0	4.5
Total	10.0	25.1	19.7	17.5	21.8

Age in years; ARI: Accident Related Injury
NARI: Non-Accident Related Injury; MI: Minor Injury

Table 7. Injury per 1000 in recent 12 months by length of employment

LOE	< 2	3-5	6-10	≥ 11	Total
ARI	11.7	3.9	13.2	18.8	12.7
NARI	2.6	0.9	3.2	2.7	2.3
MI	12.1	1.7	2.3	1.2	2.7
Total	26.4	6.4	18.7	22.7	17.8

LOE: Length of Employment in years; ARI: Accident Related Injury;
NARI: Non-Accident Related Injury; MI: Minor Injury

Affecting Variables

As for hypothesis 1 and testing Safety climate at the plant differ by size (number of employees). Firstly this study analyzed the difference in mean value between five groups. 'less than 30 employees' group recorded the biggest level (1.51) of safety climate, in contrast, 'between 100 and 499 employees' group showed the lowest (1.81). The F-test was not significant at 0.05 level (p=0.14) which implies the mean value of safety climate is similar among all plants. Accident-occurred plants (98 plants) showed 1.76 and non-accident plants (97 plants) recorded 1.70 but hypothesis 2 (Favorable safety climate at plant are associated with lower number of reported accident), was not supported at 0.05 significance level.

Table 8. The result of frequency analysis

Factors	Mean	SD
M1	1.41	0.68
M2	2.08	1.03
M3	1.70	0.90
W1	1.82	0.95
W2	2.18	0.99
W3	2.28	1.19
W4	1.68	0.85
W5	1.83	1.06
W6	1.77	0.94
W7	2.25	1.33
W8	1.87	0.93

Table 9. The result of hypothesis 1 and 2

Hypothesis	F-test value	p-value
1	1.758	0.14
2	0.924	0.34

Correll et al.[9] analyzed the benchmark safety culture scores for survey sample and the result was that plant size bears no relationship to safety culture score. Injury experience and severity have regarded as significant variable for addressing the influencing variable on safety climate in many previous studies[10,11] evaluated injured construction workers' perceptions of workplace safety climate, physical job demands, decision latitude, and coworker support, and the relationship of these variables to the injury severity sustained by the workers. The study resulted that a positive significant correlation was found between injury severity and the safety climate scores.

The first purpose of this study was to identify the level of safety climate in Korean manufacturing industry. The targeted plants have spent relatively more effort to safety environment than others because of potential major accidents that caused by hazardous chemicals. So these plants met the pre-conditions for measuring safety climate suggested by HSE[6].

The results of frequency analysis showed that 'Management commitment to safety (M1)' was the highest among plant level factors and 'Merits of the H&S procedures, instructions, and rules (M2)' recorded the lowest. On the other hand, in individual level, 'Communications (W4)' showed the highest, which was followed by 'Perceptions of organizational and management to H&S (W6)', 'Training and Competence (W1)', W5, W8, W2, W3, and 'Rule breaking (W7)' recorded the lowest level.

The results are similar to the results from Correll[9]. Most of all, both studies showed that workers were not satisfied with their jobs, and perceived positively on organizational and managerial commitment to safety. In contrast, workers' perception on communication, and on safety education and training showed very differently.

According to the outcomes, plant size (hypothesis 1) had no relationship to the level of safety climate, as the result of the previous study[9].

REFERENCES

[1] Health and Safety Executive (HSE), Summary Guide to Safety Climate, HSE Books,1999.
[2] Cullen WD, The public inquiry into the Piper Alpha Disaster, Department of Energy: HMSO, 1990.
[3] Fennell, D. Investigation into Kings Cross Underground Fire. Department of Transport, HMSO, 1988.
[4] Petersen Dan, Human error reduction & safety management, 3rd edition International Thomson Publishing, 1996.
[5] Zebroski, E., Lessons Learned from Man-made Catastrophes, in Risk Management, New York: Hemisphere Publishing, 1991.
[6] Health and Safety Executive (HSE), Safety culture maturity model, HSE Books, 2000.
[7] Cox, S. J., Cheyne, A.J.T., Assessing safety culture in offshore environments, Safety Science 34, 2000, pp.111-129.
[8] Litwin M. S., How to measure survey reliability and validity. Sage, Thousand Oaks, 1995.
[9] Michael Correll and Graham Andrewartha, Positive Safer Culture: the key to a safer meat industry, 2000.
[10] Rundmo, T., Safety climate, attitudes and risk perception in Norsk Hydro, Safety Science 34, 2000, pp. 47-59.
[11] Marion Gillen, Davis Baltz, Margy Gassel, Luz Kirsch, Diane Vaccaro, Perceived Safety Climate, Job Demands, and Coworker Support among union and nonunion injured construction workers, Journal of Safety Research 33, 2002, 33-51.
[12] David M. DeJoy, Bryan S. Schaffer, Mark G. Wilson, Robert J. Vandenberg, Marcus M. Butts, Creating safer workplace: assessing the affecting variables and role of safety climate., Journal of Safety Research 35, 2004, 81-90.
[13] Lee, T., Harrison, K., Assessing safety culture in nuclear power stations, Safety Science 34, 2000, pp. 61-97.