Original Article

Evaluation of Safety Climate Factors - a Macroergonomics Approach: a Case Study in Iran

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Objectives: The objective of this study is to evaluate the safety climate as an important part of macroergonomics domains and to determine the importance of each safety climate factor in an Iranian company.

Methods: For data gathering, the researchers used Macroergonomic Organizational Questionnaire Survey (MOQS) method. For conducting this method we applied safety climate questionnaire which has been presented by Vinodkumar et al. After distribution of questionnaires through our samples with accuracy of 5% and confidence level of 95% and gathering the questionnaires, data were analyzed using SPSS V.16 software and Entropy.

Results: The number of returned valid questionnaires was 134 out of 151 and response rate was 88.74%. Questionnaire's reliability which assessed by Cronbach's Alpha was 0.928. The results indicated that mean of safety climate score was 154/84; and 68.7% of workers had positive safety attitudes. In addition, we found a significant relationship between ages on safety climate (P< 0.05). The highest and lowest weights, which are obtained by entropy, belong to safeness of work environment and emergency preparedness in the organization with weights of 0.197 and 0.144 respectively.

Discussion: Considering catastrophic consequences of accidents in petrochemical industry, the results show the importance of attention to safety principles and to develop a positive employee attitudes related to safety.

Keywords: Safety climate, Safety of work environment, Emergency preparedness, Entropy

Introduction

Averages of 6,000 people die every day as a result of work-related accidents or diseases, totally more than 2.2 million work-related deaths per year. About 350,000 deaths out of this mortality are from workplace accidents and more than1.7 million are from work related diseases (1). An effective safety management requires attention to human factors as well as system components which makes risky or safe situations in technical components. Paying attention to human factors, organizations with high reliability can recognize hazards before occurrence. One of the most important methods for achievement to this purpose is using leading criteria such as safety climate or safety culture. People and management systems are two components of each organization (2) that together make safety climate and safety culture at organization.

International Ergonomics Association (IEA) defines ergonomics as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theories, principles, data and methods to design an optimized human well-being and overall system performance."

The macroergonomics domain deals with the overall design of work systems. Since the early days of the discipline, organizational design and management factors have sometimes been considered in ergonomic analysis and design, but it was not until

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the beginning of the 1980s that the area began to receive formal recognition as a distinct subdiscipline of ergonomics.

The term of safety culture gained its first official use in an initial report into the Chernobyl accident (3). Advisory committee on the safety of nuclear installation (4) has defined safety culture in a comprehensive manner. In their view " safety culture is the product of individual and group values, attitudes, perceptions, competencies and patterns of behavior that determines the commitment to safety, and the life style and proficiency of an organization's health and safety management.'' More specifically, safety culture is seen as a sub-facet of organizational culture (5). The concept of safety culture has its origin in the social and behavioral psychology of the 1950's and 1960's that came to the fore in the organizational psychology, organizational behavior, and management literature of the 1980's (3). As the safety culture is a subset of the overall organizational culture and subset of organizational factors, denoting the extent to which upper level management demonstrates positive and supportive safety values, attitudes and behaviors. It is one of the most stable and substantial forces within organizations, shaping the way members think, behave, and approach their work (5). Zohar (1980) coined the term safety climate in an empirical investigation of safety attitudes in an Israeli manufacturing, and defined it as '…a summary of molar perceptions that employees share about their work environments (7). As many of the definitions of safety culture and safety climate have common elements, safety climate may reflect the underlying culture of the work-group or organization, although its focus is actually much narrower than safety culture (3).

Materials and Methods

This study has been conducted in functional units of a Petrochemical Company, which is located in the south of Iran, in 2010 by using Macroergonomic Organizational Questionnaire Survey (MOQS) method. These surveys can be very useful for quickly and inexpensively identifying symptoms of work system design problems and locating where these problems may be occurring within the work system. Sometimes a problem can be identified in some work system units, and a MOQS can be developed and used to determine how widespread the problem is throughout the organization (8). For conducting this method, researchers used safety climate questionnaire (SCQ), and also they applied Entropy method to measure weight of safety climate factors. Furthermore, the relationships between safety climate and employees' demographic characteristics such as age, education, job experience, number of trainings and marriage status were examined by statistical analysis tests of t-test and ANOVA. We used safety climate questionnaire presented by Vinodkumar and M. Bhasi (9) on a 1–5 Likert scales, ranging from strongly disagree to strongly agree; we chose this questionnaire because this questionnaire was developed in the process of chemical industries similar to our field. A demographic questionnaire was used in order to gather general data. Questionnaires were distributed between total of 151 functional workers of the Company within 5 shift work groups (working day or No, A, B, C, D). Working ordinary day group works all the weekdays 8 am -17 pm, but shift work groups (A, B, C, D) work at three times in week (from 6 until 14, 14-22, and 22-6) rotationally. Their jobs are identical.

Safety Climate Questionnaire

Used SCQ consists of 49 questions and six categories. Its categories are 1) Management commitment and actions for safety (shown as F1 in the table 2), 2) Workers' knowledge and compliance to safety (F2), 3) Workers' attitudes towards safety (F3), 4) Workers' participation and commitment to safety (F4), 5) Safeness of work environment (F5), and 6) Emergency preparedness in the organization (F6).

Table 2. Cronbach's Alpha and Descriptive of each SCQ factor

Factor	F1	F2	F3	F4	F5	F6
Alpha	0.925	0.813	0.741	0.728	0.821	0.663
Average	12.14	4.46	19.88	21.56	25.97	71.52
Standard Deviation	2.59	1.842	5.60	2.36	3.67	14.45
Possible Middle score	12	9	15	15	21	75

Entropy Method

Entropy is a major conception in physics, social science, and information theory, which shows the amount of uncertainty in an expected informational content of a message (10). In other words, entropy in information theory is a criterion for uncertainty that is explained by a discontinuous probability distribution (pi). This uncertainty is calculated as eq.1.

$$E \approx S\{p_1, p_2, ..., p_n\} = -K \sum_{i=1}^{n} [p_i.Lnp_i] \quad \text{Eq. (1)}$$

Where:
K is a positive constant variable in order to supply $0 \leq E \leq 1$.
E is calculated from probability distribution pi by statistical mechanism and it is the maximum value if all of s ( ) are same. Therefore eq.2 will be obtained.

$$-K\sum_{i=1}^{n}[p_i.Lnp_i] = -K\left\{\frac{1}{n}Ln\frac{1}{n}+\frac{1}{n}Ln\frac{1}{n}+...+\frac{1}{n}Ln\frac{1}{n}\right\}$$

$$-K\{(Ln\frac{1}{n})(\frac{n}{n})\} \quad \text{Eq. (2)}$$

A decision-making matrix of a MADM model contains data that entropy can be used as a criterion to evaluate them (table 1). The available data in the decision-making matrix will be normalized by eq.3.

$$P = \frac{}{\sum} \quad \text{Eq. (3)}$$

Table 1. Decision matrix

	X1	X2	….	Xn
A_1	r^{11}	r_2	….	r_{1n}
A_2	r_{21}	r_{22}	….	r_n
⋮	⋮	⋮		⋮
A_m	r_{m1}	r_{m2}	….	r_{mn}

And for Ej from pij set in lieu of every specification we will have eq.4.

$$E = -K\sum_{i=1}^{m}[p_{ij}.Lnp_{ij}] \text{ ,That is} \quad \text{Eq. (4)}$$

Now uncertainty or deviation degree (di) from obtained data in lieu of the jth specification is so eq.5.

$$d_i = \quad \text{Eq. (5)}$$

Finally for weights (wj) of existed specification we will have eq.6.

$$w_j = \quad \text{Eq. (6)}$$

Results

The number of returned valid questionnaires was 134 out of 151 and response rate was 88.74%.

All workers were male. Average employees' age was (30.95±5.298) yrs old. Considering marriage, 63.6% of the employees were married and the rest of them were single. Regarding the education, the employees with diploma or less levels of education had the largest proportion with 38.8%. The employees with M.Sc. or higher level educations were allocated to the least proportion with 3.7%. Workers were working in four job units including operation (73.1%), maintenance (11.2%), Technical services (9.7%), and storage with (6.0%). Percentage of workers at different shift work groups of A, B, C, D and day working were 15.7, 16.4, 20.1, 17.9 and 29.9 respectively.
The results also signified that the average work experience was (6.57±4.44) yrs. In average, every worker attended five safety training courses but the range varied from 1 to 20 courses.

Reliabilities of SCQ

Questionnaire's reliability assessed by Cronbach's Alpha was 0.928. Alpha was measured for each factor of SCQ showed in table 3. Through comparing these six factors with alpha 0.7, we can see that reliability of all these six factors is optimum (11).

Table 3. Decision making matrix (based on safety climate result)

Factor / Shift work	F1	F2	F3	F4	F5	F6
D	1570	857	494	441	99	291
B	1619	600	489	440	87	253
C	1881	692	588	574	119	344
A	1530	544	447	403	103	260
No	2984	1057	871	806	189	479

Safety climate score

After calculation of each worker's safety climate score by sum of all responses' scores, the average of all of the workers' score was measured. The results indicated that mean of safety climate score was $(154/64 \pm 19/723)$ out of 245[1]. Table 3 shows average score of safety climate and its components (sum of all responses' scores for each one).
Since, mean score on safety climate was more than 147[2] (as middle score), it shows that, safety climate was positive in the company.

1- 49 (number of questions)× 5(maximum score for each question)=245
2- 49 (number of questions)× 3(middle score for each question)=245

In other words, 31.3% of workers had negative status and 68.7 % had positive status.

The relationship between safety climate score and age is significant ($p<0.05$) by Pearson correlation, correlation coefficient was 0.172 which means that as the employees get older the safety climate score is increasing. However, results didn't declare any other significant relationship between safety climate score and other demographic characteristics.

Results Based on Applying Entropy Method

In this study six factors of safety climate ($n=6$) in five shift work groups ($m=5$) were assessed. Table 4 shows decision making matrix which contains total score of safety climate factors for each work shift group.

We calculated the sum of each column ($i= 1,\ldots, 6$), and then divided each datum by column sum of that datum to obtain matrix of p_{ij}.

Then we calculated the Ln of each datum of p_{ij} matrix. Each grid of new matrix must be multiplied by the same grid in p_{ij} matrix. We calculated the sum of each column in this new matrix. There would be 5 numbers obtained for safety climate factors, which multiplied by -0.621 (-1/Ln m).

According to using Entropy method each safety climate's factor is calculated as shown in table 4.

Table 4. Calculating the importance of each safety climate factors by Entropy

Priority (based on importance)	Safety climate factor	Obtained weight by Entropy
1	Safeness of work environment	197.0
2	Workers' participation and commitment to safety Management commitment and actions for safety	174.0
3	Workers' knowledge and compliance to safety	159.0
4	Workers' attitudes towards safety	152.0
5	Emergency preparedness in the organization	144.0

Conclusion

Results have shown that about one-third of workers have negative safety climate, and by taking into account the catastrophic consequences of accidents in petrochemical industry negative status must be in lower amounts in these kinds of workplaces. So, the results declared the importance of attention to increase positive safety climate among the employees; this policy would result in safety climate promotion and finally safety culture improvement in the organization. In order to achieve this goal, we can focus on these factors: a. Safeness of work environment, b. Workers' participation and commitment to safety c. Management commitment and actions for safety. As these factors are located in the first, second and third priorities respectively, according to Entropy method results, concluded that improvement in company safety climate would be achieved by more attention to these factors. We desire that this kind of activity for safety climate improvement will lead to positive and permanent results in the company because this program will be conducted by workers and management will support them. We can expect that workers' behavior would be improved by safety climate promotion (12) and by this promotion, work related accidents and injuries would be decreased. However, it should be considered that changing culture from a negative to a positive status is a prolonged and time taking process.

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