Original Article *J Res Health Sci, Vol. 9, No. 2, 2009, pp. 10-18*

The Evaluation of Importance of Safety Behaviors in a Steel Manufacturer by Entropy

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(Received 18 July 2009; accepted 11 Sep 2009)

Abstract

Background: This study aimed to evaluate the workers safety behavior and to determine the importance of each unsafe behavior in an Iranian steel manufacturing company.
Methods: This study was conducted in Mobareke steel manufacturing company, which is located in the middle of Iran, in 2007. The methodology was based on the safety behavior sampling (SBS) technique and entropy. After specifying the unsafe behaviors and with reference to the results of a pilot study a sample of 3248 was determined, with a sampling accuracy of 5% and confidence level of 95%.
Results: The results indicated that 41.8% of workers behaviors were unsafe. The most frequent unsafe behaviors were inappropriate use of personal protective equipments (PPEs) with 32% of total unsafe behaviors. The results also notified a significant relationship between age, job experience and educational level on unsafe behaviors ($P< 0.05$). The highest weight, which is obtained by entropy, belongs to using inappropriate tools with weight of 0.1425. The ultimate findings of the study showed that a considerable number of workers' behaviors were unsafe, which is one of the main antecedents of industrial accidents.
Conclusion: Considering catastrophic consequences of accidents in steel manufacturing industry, the results emphasize on diminishing unsafe behaviors and recommends applying behavior based safety principles.

Keywords: *Safety behavior sampling, Unsafe acts, entropy, Steel manufacturing company, Iran*

Introduction

Although the development of science and technology has already decreased the number of employees in industries, there has been a developing trend in terms of employees' importance in workplaces (1). Controlling a large number of different and critical operations is the duty of human beings in modern industries. It is usually assumed that making errors is one of the main contributors to catastrophic disasters likelihood (2). Disastrous accidents like Chernobyl, Three Mile Island and Boopall are all examples of these kinds (3).
Due to the catastrophic consequences of such accidents, human beings always try to take controlling measures and reduce the potential risks (4). Before the 1930's safety specialists followed the prevention approaches by using physical methods such as machine guarding, housekeeping and inspection programs (5). Until that time, it was believed that the main causes of industrial accidents were unsafe conditions and physical hazards such as heavy equipment, trenches, mechanical explosions, ionizing radiation, flammability, corrosion, reactivity, fast moving vehicles, steep grades, uneven surfaces etc. It was in the early years of 1930's when the concept of unsafe acts and their role in causing industrial accidents were introduced (5) and the theory of" human beings as the first antecedents (trigger reason) of accidents by doing

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unsafe acts" was propounded by Heinrich in his book "prevention of industrial accidents" (6). Heinrich stated that roughly 88% of all accidents were caused by human errors (3). Drew estimated that 80% to 90% of the accidents were caused by human errors (7). In addition, Reynard and Billings came to this conclusion that human's unsafe acts caused 70% to 90% of the accidents (7). This drew psychologists and safety specialists' attention to unsafe acts as the most probable cause of frequent accidents happening in industries. In order to diminish the likelihood of such accidents, this group of specialists emphasized the behavior of employees using behavior science techniques (8). Social psychologists recognize "attitude" as the most important factor to predict employees' behaviors. In other words, these efforts led to initiation and development the "behavioral based safety" approach.

These studies present an entropy method for evaluation of unsafe behavior in steel manufacturer. Moreover, previous studies concentrate and use Delphi method for evaluation of importance of unsafe behavior. However, we claim that entropy provides more reliable solutions in context of the importance of unsafe behavior than which is a good substitute for expert judgment. This is quite important in situations, where there are no expert judgments available or is also impossible to use expert judgment for evaluation of unsafe behavior.

The purpose of this investigation was to specify the type, proportion, and importance of unsafe acts in employees' behaviors. Furthermore, the relationship between unsafe behaviors and employees' demographic characteristics such as age, education, job experience, and marriage status was examined. It is also worth mentioning that in this research, an unsafe act is defined as a behavior that is committed without considering safety rules, regulation, standards and specified criteria in system, which can affect the system safety level (9).

Materials and Methods

This study was conducted in the Operational Department of Mobareke Steel Manufacturing Company, which is located in the middle of Iran, in 2007. Safety Behavior Sampling (SBS) technique was employed to conduct this study. SBS is a technique of measuring unsafe acts and is based on the laws of probability (10, 11).

In order to obtain a complete and accurate picture of safe/unsafe acts performed by the worker, it is necessary to observe continuously the worker and record data related to unsafe acts (12). Note that a sufficiently large sample must be obtained for representative results (13) and consists of previous accidents records, including disabling injuries, recordable injuries and first aid cases, interviews with the managers and experts of the department and the review of the related documents. The obtained list was adjusted based on present conditions such as type and nature of work, reviews of accidents reports, present cultural conditions, and a number of related factors.

After specifying the unsafe acts, a number of necessary observations of workers' behaviors were carried out in order to determine the proportion of their unsafe acts.

The number of observations required is based on data collected during the pilot study, the degree of accuracy required, and the given level of confidence.

Total number of required safety behavior observations is derived from (14):

$$N = \frac{\left[Z0.95^2(1-P)\right]}{e^2\mathrm{P}}$$

(Eq. 1)

For a given level of confidence K, the value of K is read from the standardized normal tables. For 95% confidence, K is approximated as 2, and for 99% confidence, K is taken as 3.

Confidence level means that the conclusions will be representative of the true population 95% of the time. Accuracy may be interpreted as the tolerance limit of the observations that fall within a desired confidence level. 5% accuracy with 95% confidence level is the combination often used in safety behavior sampling. This means that 95% of the time within 5% accuracy limit, the conclusion drawn based on safety behavior sampling will be representative of the actual population (15).
After conducting a pilot study the proportion of unsafe acts were estimated to be about 33%. Considering that 5% accuracy with 95% confidence level is the combination, which is often used in safety behavior sampling, the total number of observations was estimated to be 3248.
Safety behavior sampling needs to be done randomly. This is achieved when each period of the workday is equally selected as the observation period. Therefore, in the next stage the observations are done randomly. This means that both observed workers (64 workers of operational department) and frequency of observations (in the period of 8 hours from 7 to 15) were selected randomly.
Since the behavior of human beings might be changed from time to time, the observation duration has a vital role in accuracy of the results. This duration should be as short as possible to observe and specify the behaviors. In this research, the average of each duration was 2 seconds.
The observations were carried out randomly by the researcher while the subjects were not aware of the fact that they were being observed.
In order to recognize the relationship between the employees' demographic characteristics and unsafe behaviors, the mentioned variables such as age, work experience, education, previous accidents records and marriage status were collected through interviews and a special questionnaire. In each questionnaire, there were questions about age, education, job experience, previous accidents records. Having been chosen randomly, subjects were questioned by the researcher and their answers were recorded.
It is worth noting that the collected data were analyzed with SPSS and was tested by Kruskal-Wallis test and one-way ANOVA.
In the previous studies to find the importance of unsafe acts DELPHI method and application of questionnaire were used, which were based on concept and background of the experts, but in this study to find the importance of each unsafe act, a mathematical method, entropy, which was more reliable, was applied.

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. In another word, entropy in information theory is a criterion for uncertainty that is explained by a discontinuous probability distribution (p_i). This uncertainty is calculated as followed:

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

(Eq. 2)

K is a positive constant variable in order to supply $0 \leq E \leq 1$.
E is calculated from probability distribution p_i by statistical mechanism and is maximum if all of p_is $(p_i = \frac{1}{n})$ are same. Therefore:

$$-K\sum_{i=1}^{n}p_i.Lnp_i = -K\{\frac{1}{n}Ln\frac{1}{n} + \frac{1}{n}Ln\frac{1}{n} + \ldots + \frac{1}{n}Ln\frac{1}{n}\} =$$
$$-K\{(Ln\frac{1}{n})(\frac{n}{n})\} = -KLn\frac{1}{n}$$

(Eq. 3)

A decision-making matrix of a MADM model contains data that entropy can be used as a criterion to evaluate them. A decision-making matrix is showed below.

A decision-making matrix

	x_1	x_2	…	x_n
A_1	r_{11}	r_{12}	…	r_{1n}
A_2	r_{21}	r_{22}	…	r_{2n}
⋮	⋮	⋮	…	⋮
A_m	r_{m1}	r_{m2}	…	r_{mn}

The available data in the decision-making matrix will be so normalized:

$$P_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}$$

(Eq. 4)

And for E_j from p_{ij} set in lieu of every specification we will have:

$$E_j = -K\sum_{i=1}^{m}[p_i.Lnp_i];\forall j$$

(Eq. 5)

That is K=1/Lnm.

Now uncertainty or deviation degree (d_i) from obtained data in lieu of the j^{th} specification is so:

$$d_j = 1 - E_j;\forall j$$

(Eq. 6)

Finally for weights (w_j) of existed specification we will have:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

(Eq. 7)

If decision maker already has a conceptional judgment (λ_j) as the relative importance for the j^{th} specification, then w_j will be modified as followed:

$$w'_j = \frac{\lambda_j.w_j}{\sum_{j=1}^{n}\lambda_j.w_j}$$

(Eq. 8)

In this research in order to distinguish of unsafe acts in sub-companies following steps were done:

Determining the frequencies of each unsafe act in every sub-company of the steel manufacturing company and filling the matrix.

First calculate the sum of each column (i= 1, …, 7), then divide each datum by column sum of that datum to obtain matrix of p_{ij}.

Calculate 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.

Calculate the sum of each column in this new matrix. There will be 20 numbers will be obtained for 20 unsafe acts, which will be multiplied by -0.514 (-1/Lnm). This new numbers are E_j.

Here there is no need to d_j and w_j will be calculated as followed:

$$w_j = \frac{E_j}{\sum_{j=1}^{20} E_j}$$

(Eq.9)

Results

A total of 3248 observations were conducted in this study. From these observations, the proportion of unsafe acts was 41.8%. Among unsafe acts, inappropriate use of personal protective equipments (PPEs) was allocated itself as the largest proportion (32%) of the unsafe acts. Application of inappropriate tools and settling in inappropriate place with 14% and 13% of all unsafe acts stood respectively in the second and third grade. Employees from 40 to 49 yr, were the most dominant and frequent age group among observed subjects. They made up 46% of all sampled population. On the other hand, subjects above 60 had the lowest frequency with 2.6%. The results and frequencies of age groups were shown in Table1.

Considering marriage, 91.2% of the employees were married and rests of them were single. Moreover, regarding the education, the employees with high school education degrees had the largest proportion with 48.9%. The employees with academic educations allocated themselves to the least proportion with 6.5% (Table 1).

The results also signified that the work experience of the workers varied from 0.5 to 35 yr and among them, those whose work experience was less than 5 yr formed the most proportion of the observed employees with 44% (Table 1).

A Kruskal-Wallis test was used to evaluate the effect of age, education, marital status, and work experience on unsafe act. The results are shown in Table 2.

Frequencies of each unsafe act in every sub-company of the steel manufacturing company are shown in Table 3. Accordingly, the relations between age and work experience on the number of unsafe behaviors, are statistically significant (*P*< 0.05). The results showed an inverse relationship between the unsafe behaviors with age and also for work experience. Which means, as the employees get older; the number of unsafe behaviors is reduced.

To determine the importance of each unsafe behavior, their weights calculated with entropy method. The highest weight belongs to "using inappropriate tools" with weight of 0.1425. The obtained weights are showed in Table 4.

Table1: Frequencies of individual according to age, education and work experience

		(%)
Age groups	22-29	15.3
	30-39	29.6
	40-49	46
	50-59	6.5
	X≥ 60	2.6
Education	Primary school	16.1
	Junior high school	23.2
	High school	48.9
	Academic	6.5
Work experience (Year)	0-5	44
	6-11	17
	12-17	4
	18-23	21
	24-35	14

Table 2: Effect of age, education, marital status, and work experience on unsafe act

Parameter	*f*	significance	H_0
Experience	52.6	0.009	accepted
Age	59	0.012	accepted
Educational level	8.87	0.033	accepted
marital statue	0.073	0.878	Not accepted

Table 3: Frequencies of each unsafe of sub-company

Type of unsafe acts \ Company	1	2	3	4	5	6	7
Inappropriate PPE	12	2	25	0	2	0	1
Using inappropriate tools	3	7	4	0	1	2	1
Settling in a dangerous place	2	0	12	0	0	3	0
Moving under hanging load	3	5	0	3	0	0	2
Inappropriate posture	1	1	5	0	0	0	0
Work interference	0	0	0	1	2	1	0
Making tools unsafe	0	1	2	0	0	1	0
Unsafe load transfer	2	0	0	1	0	0	0
Working with defective machine	1	0	1	0	0	0	0
No attention to crane's tocsin	0	2	1	0	0	0	0
Running or jumping from height	0	0	0	0	1	1	0
Unallowable presence in crane's cabin	0	0	0	2	0	0	0
Horseplay during work	1	0	1	0	0	0	0
Washing tandish with alcohol during work	0	0	0	0	0	2	0
Lack of control during metal casting	0	0	2	0	0	0	0
Misuse of compacted air	1	0	0	0	0	0	0
Dangerous driving	0	1	0	0	0	0	0
Moving indirectly	0	0	1	0	0	0	0
No riggers	0	0	1	0	0	0	0
Not using colored signs during sampling	0	0	1	0	0	0	0

Table 4: calculating the importance of each unsafe behavior with entropy

Type of behavior	Obtained weight by entropy
Inappropriate PPE_s	0.095
Using inappropriate tools	0.1425
Resting in unsafe place	0.073
Moving under Suspended load	0.121
Awkward Posture	0.072
Work interference	0.094
Making tools unsafe	0.094
Unsafe load handling	0.057
No attention to crane's alarm	0.058
Working with unsafe machine	0.063
Running or jumping	0.063
Unauthorized presence in crane's cabin	0.00009
horse playing	0.063
Washing tandish with alcohol during work	0.00009
Lack of control during metal casting	0.00009
Work with compressed air	0.00009
Dangerous driving	0.00009
Moving indirectly	0.00009
No rigger	0.00009
Not using colored signs during sampling	0.00009

Discussion

The results of the current research in gas treatment company indicated that a large number of employees' behaviors were unsafe (41.8%) which seems to be quite less than the results of previous studies. The rate of unsafe behaviors in other researches in a foundry and a metal working company in Iran were 59.2% and 27% respectively (16).

The consequences of unsafe behaviors depend on different factors such as the nature of the tasks and the type industry. From safety specialists' point of view, the steel manufacturing company is a critical workplace due to its high complexity, low flexibility, and high vulnerability towards accidents. Although in the studied company the proportion of unsafe behaviors is approximately low, the risk of such behaviors is unacceptable due to their serious consequences (16), thus the aforementioned proportion of 41.8%, as a marginal value in a Steel manufacturing Company, considered unacceptable.

The most frequent and important behavior was inappropriate use of personal protective equipments (PPEs) with 32% of all unsafe acts. Inappropriate uses of PPEs have always been one of the basic factors in accidents. The use of inappropriate clothes and garments reported as one of the 6 basic triggers of accidents from 1994 to 2003 in Iran (16). Plenty of reasons can be mentioned for inappropriate use of PPEs such as lack of workers knowledge about workplace hazards and PPEs, ignoring workers opinions in selecting and purchasing PPEs and insufficient supervision in terms of using PPEs properly (17).

Modern safety approaches lay a great emphasis on identifying and controlling the hazards by administrative and engineering practices. According to this, controlling methods that directly depend on workers 'level of acceptance and participation (such as using of PPEs) are not in top priorities and should be taken as the last resort (17). An important and effective factor for PPEs programs to be successful is employees' acceptance and participation (17).

Without considering this issue, it is almost obvious that, in spite of all plans, policies, or measures, not only the PPEs programs cannot be successful but also they can have some undesirable results.

Some factors that might influence employees' acceptance are their frequent participation in selecting proper equipment, conducting training and retraining programs on maintaining, cleaning, and using PPEs. A complementary study in company notified that 79.8% of the workers believe that the use of safety equipment in workplace is necessary, meanwhile 33.9% of them had developed this opinion that the PPEs are mainly uncomfortable and 32% of them believed old, worn out and expired PPEs were not substituted with new ones regularly (16).

In summary, the main reasons related to high frequency of unsafe behavior occurrence in terms of PPEs uses are:
Selecting PPEs without considering task safety analysis, employees' characteristics and present hazards.
Lack of appropriate trainings about hazards communication.
Insufficient participation of personnel in PPEs programs.
It is concluded that 59% of all unsafe behaviors in this steel manufacturing company consist of inappropriate use of personal protective equipments, application of inappropriate tools and settling in inappropriate place. With more attention to the antecedents, the number of unsafe behaviors can be reduced resulting in amore efficient accident prevention system.
Having studied the relationship among different variables and the number of unsafe acts these results were obtained:
There is an inverse relationship between unsafe behaviors with age. As employees grow older, the proportion of unsafe behaviors is reduced. It might be related to the higher work experience and workmanship level and the fact that older employees are usually more skillful.
It is a general view that adolescents are more likely to take risks than middle-aged and older people are. This opinion is supported by results from traffic studies, which have shown that young drivers tend to drive faster, follow with shorter headways, and not wear seat belts as often as older drivers (18, 19).
There is an inverse relationship between unsafe behaviors with education. Employees with higher educational level behave safer than low educated personnel.
Accidents tend to accumulate on new inexperienced workers (20). For example, the risk of a woodworker having an accident on his/her first day on the job can be as much as 50 times higher than that of a worker with 1 year's work experience (21). The accident risk generally decreases as work experience increases (22).
There was also a significant relationship between work experience and previous accidents. This implies the fact that the more work experience people have, the more accident they might have experienced.
No considerable relationship was found between unsafe behaviors and marital status $P>0.05$).
In order to improve safety behavior of workers, a comprehensive program must be introduced.
This could be comprised of implementation of appropriate safety management systems, identify and correct unsafe conditions such as temperature or humidity extremes, unguarded equipment, uncovered floor openings, safety training programs, lecture series etc (23, 24). The safety behavior sampling study may be conducted on a weekly basis during and upon the completion of the program. The safety behavior control chart for each period following the beginning of the program will show if a significant improvement in unsafe behavior has been achieved. Modification of the program or its components may be carried out as long as the unsafe behavior is being reduced. Once the minimum number of unsafe behavior has been achieved (i.e. p), the behavior sampling study may be repeated and the obtained data plotted on the control chart to assure that the frequency of unsafe behaviors remain at the desired minimum level.
Considering the results, the following items are suggested:
1. Employing task risk analysis methods to screen and determine risky jobs in order to perform ergonomic evaluations and appropriate interventions.
2. Setting and implementing an executive system to accomplish PPEs programs successfully. Such programs mainly include appropriate selecting, maintenance and cleaning of PPEs.
3. Design and implementation of accident prognoses tests before employment in order to recognize and screen employees with higher natural tendencies in causing accidents. This

might prevent such employees from doing critical (safety concerned) jobs.
4. Planning and conducting safety-training programs based on behavioral based safety in steel manufacturing company in order to improve unsafe behaviors and change false safety attitudes consequently.
5. Design and implementation of punishment and award system considering employees patterns of behaviors.
6. Periodic evaluation of workers' behaviors in order to provide proper inputs for interventions and measuring their effectiveness.
7. Implementation of a risk management system to determine the risk of unsafe behaviors and presenting suitable engineering and administrative controlling methods.

Acknowledgements
The authors are grateful for the valuable help and support received from Dr. Hossein Modaresifar and all those who helped in the study. The authors declare that there is no conflict of interests.

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