Prioritizing Critical Success Factors Influencing Safety, Using TOPSIS

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Abstract

Undoubtedly, one of the most important subjects in organizations is preserving personnel healthy and preventing accident in work environment. Therefore, identification of influential factors on safety as a critical issue has always been given significant consideration. These methods can help managers to find some good ways to improve the employees' work condition. In this paper, the Critical Success factors which may influence safety are addressed and in the following the CSFs are prioritized in terms of different departments. TOPSIS method as a suitable multi criteria decision making instrument is applied to select the principal ones. Organizations can improve their own safety through consideration on the most significant CSFs which are in priority.

Keywords: Safety, Critical Success Factors (CSFs), TOPSIS, Multiple Criteria Decision Making (MCDM)

1. Introduction

One of the main challenges of organizations is decreasing the number of frequent accidents at the workplace (Sawacha et al., 1999). It has been proved that safety programs as a proactive action may lead to departments' performance improvement. These programs provide a safe environment for employees and consequently can help managers to prevent occurrence of accidents (Rowlinson, 2003). Moreover, the mutual cooperation between managers and workers in term of an effective safety program can develop safety culture in the organization. Since a safety program interrelate with various dimensions of an organization, it is very important to involve different related items with safety programs (Findley et al., 2004)

Grassi et al. (2009) exploited an integrated methodology based on fuzzy logic theory and TOPSIS technique to prioritize hazardous activities. They represented a fuzzy multi-attribute model for evaluating risk in a workplace. Findings of this research denote that injury magnitude and occurrence probability are the most important factors. In a study by Yang et al. (2009) proposed a hybrid methodology to describe the role of Baysian Network and multiple utility techniques in safety management. The proposed methodology was able to address risk factors and prevent the problems resulting from exclusive states expressed by linguistic variables. Gran et al. (2007) developed a model-based risk assessment approach for addressing different dependability factors in a critical application. Availability, safety and security, and reliability were indispensable factors for assessment of dependability degree of total system. In another study conducted be Vogt et al. (2010), human factors and its influence in safety –critical situations were examined. In this study a human resource performance management model and balance score card technique were exploited to identify the most critical human factors.

In this paper, critical success factors of safety are considered as criteria for evaluating departments. Data are gathered through a questionnaire based on 16 critical success factors in five different departments. To evaluate department and to prioritize CSFs, TOPSIS and Entropy method is used respectively. Finally, a case study is presented to prove the capability of proposed approach. Findings of this study reveal that clear and realistic goals and program evaluation are the most important factors.

2. Critical Success Factors in Safety

Critical success factors can be defined as items that if they are satisfactory, they will ensure successful implementation of a safety program (Rockart, 1979). Rungasamy et al. (2002) stated that CSFs are necessary to the success of any program in a way that if organizations' goals are not compatible with the current condition, their programs will fail catastrophically. It is also believed that the success of safety programs can be increased if the required conditions are provided. Aksorn and Hadikusumo (2008) proposed a comprehensive list of critical success factors which may influence successful implementation of a safety program. (Table 1)

3. TOPSIS

TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) method is demonstrated by Chen and Hwang (1992). The basic principle is that the chosen alternative must have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution. Different method can be used determine the weight of factors. In this study Entropy method is exploited to identify the weights of each factor.

Shannon and Weaver (1948) proposed the entropy concept, which is a measure of uncertainty in information formulated in terms of probability theory. Since the entropy concept is well suited for measuring the relative contrast intensities of criteria to represent the average intrinsic information transmitted to the decision maker, (Zeleny, 1996), conveniently it would be a proper option for our purpose.

Shannon developed measure H that satisfied the following properties for all p_i within the estimated joint probability distribution P (Zitnic and Kanade, 2004):
It is proved that the only function that satisfied these properties is:

$$H_{Shannon} = -\sum_i p_i \log(p_i)$$

Shannon's concept is capable of being deployed as a weighting calculation method (Wang and Lee, 2009), through the following steps:
Step 1: Normalize the evaluation index as:

$$P_{ij} = \frac{X_{ij}}{\sum_j X_{ij}}$$

Step 2: Calculate entropy measure of every index using the following equation:

$$e_j = -k\sum_{j=1}^{n} P_{ij} \ln(P_{ij})$$

Where $k = (\ln(m))^{-1}$
Step 3: Define the divergence through:

$$div_j = 1 - e_j$$

The more the div_j is the more important the criterion $j_{th.}$
Step 4: Obtain the normalized weights of indexes as:

$$w_j = \frac{div_j}{\sum_j div_j}$$

The TOPSIS procedure consists of the following steps: (Opricovic and Rzeng, 2004)

(1) Compute the normalized decision matrix. The normalized value r_{ij} is calculated as:

$$r_{ij} = \frac{f_{ij}}{\sqrt{\sum_{j=1}^{J} f_{ij}^2}} \quad j = 1,...,J \quad i = 1,...,n$$

(2) Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as:

$$V_{ij} = w_i r_{ij} \quad j = 1,...,J \quad i = 1,...,n$$

Where wi is the weight of the ith attribute or criterion, and $\sum_{i=1}^{n} w_i = 1$

(3) Determine the ideal and negative-ideal solution.

$$A^+ = \left\{ v_i^+, ..., v_n^+ \right\} = \left\{ \left(\max v_{ij} \middle| i \in I' \right), \left(\min v_{ij} \middle| i \in I'' \right) \right\}$$

$$A^- = \left\{ v_i^-, ..., v_n^- \right\} = \left\{ \left(\min v_{ij} \middle| i \in I' \right), \left(\max v_{ij} \middle| i \in I'' \right) \right\}$$

Where I' is associated with advantage criteria, and I'' is associated with cost criteria.

(4) Calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as:

$$D_j^+ = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^+)^2} \qquad j = 1, ..., J$$

Similarly, the separation from the negative-ideal solution is given as:

$$D_j^- = \sqrt{\sum_{i=1}^{n} (v_{ij} - v_i^-)^2} \qquad j = 1, ..., J$$

(5) Calculate the relative closeness to the ideal solution. The relative closeness of the alternative aj with respect to A^* is defined as:

$$C_j^+ = \frac{D_j^-}{\left(D_j^+ + D_j^- \right)} \qquad j = 1, ..., J$$

(6) Rank the preference order.

4. Evaluating Departments Based on Safety Criteria

In this study a questionnaire including 39 questions was designed and distributed into five different departments. Questions were designed based on the 16 CSFs in Table 2 in order to measure perceptions of respondents from the condition of factors in each department. Questionnaires were submitted to all the managers and supervisors of departments. To measure the condition of CSFs in departments, respondents were asked to rate on a five-point Likert scale varying from "very bad" (1) to "very good" (5). Collected data are represented in table 2.

The weight of each criterion is calculated by Shannon Entropy method. As considerable in table 3, the highest rank refers to program evaluation, good communication and appropriate safety education and training.

To prioritize departments, TOPSIS method is applied. As considerable in table 4, department 5 and 3 have the highest rank respectively.

5. Conclusion

During the past decade, great number of accidents has prompted scholars to investigate into the factors which may influence successful implementation of a safety program. Since a safety program involve different aspects of a department, it is important to distinguish the most important factors which may influence successful implementation of a safety program. This research presented a practical methodology for identifying the main reasons of success in safety programs implementation and ranking departments based on 16 critical success factors of safety. The methodology of this research presented an appropriate and simple way for determining the main factors which may improve departments' performance.

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7. References

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Table1- CSFs in safety implementation (Aksorn and Hadikusumo 2008)

Code	Factor	Discussion
C1	Clear and realistic goals	Safety programs can accomplish the desired results when safety goals have been clearly established. The safety goals should give a clear picture, direction and focus for performing day-to-day activities in order to reach desired results. When realistic and achievable goals are set up, the progress towards accomplishing such goals can be easily measured
C2	Good communication	When the lines of communications between management and workforce are open, workers can bring reports of unsafe working practices and hazardous Environments to management's attention. Management in turn can also communicate their concerns and priorities of safety to gain employees' compliance and awareness
C3	Delegation of authority and responsibility	Any one individual cannot make a safety program successful. Therefore, responsibility to safely accomplish activities must be transferred to individuals at lower levels of authority. Effective delegation involves granting adequate authorities and assigning clear responsibilities to perform specific tasks with enough resources such as appropriate completion time, money, and cooperation of all involved parties
C4	Sufficient resource allocation	The goals of safety programs cannot be accomplished without adequate resources. An effective safety program results from the commitment of the top management to providing an appropriate level of resources. Management must consider and allocate sufficient resources to carry out day-to-day activities to accomplish both short-term and long-term goals. The resources required for effective safety program may includes sufficient staff, time, money, information, methods used in safety works, facilities, tools, machines, etc.
C5	Management support	It is evident that management plays a very important role in an efficient and effective safety program. Management must fully and actively translate ideas into safety actions, including issuing a written comprehensive safety policy, allocating sufficient resources, promptly reacting to safety suggestions and complaints, attending regular safety meetings and training, regularly visiting the workplace, following the same safety rules as others, etc.
C6	Program evaluation	Safety programs should be periodically evaluated to determine its success in meeting set out goals and objectives. When the implementation of a safety program does not meet the defined goals, an evaluation process can facilitate in identify the shortcomings of the program and thereafter, areas for improvements can be traced and reviewed accordingly
C7	Continuing	Successful safety programs largely depend on employee involvement as workers tend to

	participation of employees	support the activities that they themselves help to create. Workers should be given the opportunities to provide input into the design and implementation of safety programs such as being a member of the safety committee, reporting hazards and unsafe practices to supervisors, identifying training needs, investigating accidents, etc.
C8	Personal motivation	Although workers have adequate knowledge and skills to accomplish their jobs safely they will not however, work in such manner unless they are motivated to do so. To ensure commendable safety records, all personnel in the workplace must be motivated to carry out their job responsibilities safely, by the possibilities of achievement and recognition, opportunity for additional responsibilities, rewards, and personal growth.
C9	Personal competency	A successful safety program also results from placing the right person on the right job. The right person is defined as the person(s) who are physically and mentally capable for carrying out the assigned tasks with the right knowledge, experience and skills
C10	Teamwork	A safety program succeeds when all concerned parties from top to bottom hierarchical levels realize that preventing accidents is everyone's responsibility. Every functional unit must cooperate in achieving the goals set by the team such as planning and controlling their works, handling day-to-day safety problems, etc.
Code	Factor	Discussion
C11	Positive group norms	Group norms are the accepted attitudes about various things amongst a group of People. In practice, members of a group conform to certain attitudes simply to avoid sanctions. If positive attitudes towards safety can be built and embedded within a group, safety can then be managed successfully. This is the basis of good safety culture
C12	Personal attitude	Attitude is a tendency to respond positively and/or negatively to certain persons, objects or situations and is normally built up through experience. Individuals, however, differ in their perception of risks and willingness to take risks. Successful safety programs can be achieved if the positive attitudes of employees toward safety are reinforced
C13	Effective enforcement scheme	Not conforming to safety rules is known as a violation. Violation need to be encountered with enforcement. Management must therefore provide the means of enforcing workers, especially the violators, to obey the safety rules and regulations. By providing an effective enforcing mechanism, management will faceless cases of violations by employees
C14	Safety equipment acquisition and maintenance	The workplace must be carefully assessed to determine possible hazards in order for proper selection of safety equipment. An effective safety program results in fewer injuries due to proper safety equipment' acquisition and maintenance. Managing a safety equipment program takes up not only a large percentage of time for purchasing the correct equipment, maintaining them good condition, and inventory control, but it also requires a good cooperation amongst the safety manager/head, purchasing, production, warehouse supervisor, maintenance managers, etc.
C15	Appropriate supervision	A sound safety program requires employers to provide sufficient supervision in protecting workers form workplace hazards. Successful supervision requires competent personal to assign work in line with the workers' ability, appraise workers when they do jobs safely, communicate by listening and speaking, set a good example by following the same safety rules and correct arising safety problems
C16	Appropriate safety education and training	A successful safety program can be achieved if all employees are given periodic educational and training programs in order to improve their knowledge and skills on safety at work

Table2- Data of five departments on 16 critical success factors

	C1	C2	C3	C4	C5	C6	C7	C8
Department1	3.47	4.12	3.75	4.25	4.11	3.11	4.09	4.19
Department2	4.12	4.07	3.76	3.89	3.77	3.92	3.29	3.86
Department3	3.87	3.48	4.29	3.92	4.06	4.15	3.75	3.91
Department4	3.95	4.41	3.93	4.14	3.95	3.65	3.85	4.26
Department5	4.28	3.85	4.18	4.33	4.23	3.54	3.93	3.76
	C9	C10	C11	C12	C13	C14	C15	C16
Department1	3.92	4.51	4.16	3.66	3.73	4.16	4.28	3.77
Department2	4.29	4.1	4.08	3.33	3.45	3.96	4.21	3.19
Department3	4.27	4.07	3.94	4.09	3.66	4.26	4.17	4.01
Department4	4.1	4.33	3.84	3.91	3.83	3.88	3.89	3.59
Department5	3.87	4.39	4.24	3.48	3.56	4.23	4.33	3.47

Table3- Weight of criteria by Entropy

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
Weight%	8.99	11.21	5.53	3.35	2.76	17.17	9.58	4.33
Criteria	C9	C10	C11	C12	C13	C14	C15	C16
Weight%	3.29	2.89	2.36	10.29	2.41	2.51	2.51	10.82

Table4- Departments' ranking

Item	TOPSIS Index	Rank
Department1	0.213401	5
Department2	0.647484	3
Department3	0.709641	2
Department4	0.543316	4
Department5	0.763191	1