AN ANALYTICAL HIERARCHICAL PROCESS FOR PRIORITISING THE SAFETY MANAGEMENT ELEMENTS FOR A MANUFACTURING ORGANIZATION IN BANGLADESH

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ABSTRACT

This paper identifies typical hazard and risk elements in a manufacturing organization, studies management elements currently used in the organization, and presents an Analytic Hierarchy Process (AHP) decision model for assessing the priority of safety management elements. Specifically, the paper addresses a hierarchy decision model for assessing the priority of safety management elements of a battery manufacturing company in Bangladesh. Safety management elements and decision criteria are identified by using OSHA and NIOSH standards. Empirical data are collected through personal interviews with safety personnel, experts and professionals in the battery manufacturing company and through spot surveying. Using the Analytical Hierarchy Process, a list of six decision criteria and ten safety management elements, which constitute the AHP alternatives, are identified and their relative importance is evaluated. Using AHP methodology, the top three safety elements that have been identified and are needed to implement a Safety Management System (SMS) include a personal protection program, emergency preparedness and safety organization. The identification of core decision criteria and safety management elements found in this research may be useful for effective implementation of SMS in manufacturing organizations.

Keywords: Analytical Hierarchy Process (AHP), Safety management elements (SMS), Health and safety, Decision making, Manufacturing organization.
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1. Introduction

A safety management system (SMS) is an explicit element of the corporate management's responsibility which explains a company's safety policy and defines how it intends to manage safety as an integral part of its overall business. Current trends show that organizations are beginning to invest attention into the organizational and management impact of safety performance, particularly the function of health and safety management. The interest in health and safety management is a result of major disasters that highlighted the failure of management to protect the health and safety of their workers and comply with the Occupational Health and Safety Act which calls them to fulfill their responsibilities as an employer to ensure that workers have a safe work-place (Hale, Heming, Carthey & Kirwan, 1997). In general, legislation is inadequate to address problems that many organizations experience in managing health and safety in the workplace. This is largely due to the "people" element where people tend to engage in safe or unsafe behavior according to their own interpretation of the rules, and that unsafe behavior then leads to accidents. Safety experts Fleming and Lardner (1999) discovered that human factors contributed to 80 – 90% of all industrial accidents as people neglected the correct procedure for performing their job. For this reason, effective health and safety management and its relation to productivity have been considered an important element when managing the interaction between systems and people. Currently, safety and health protection has become a major positive factor in favor of economic growth and productivity (Abdul Raouf, 2004). Industry concerns have focused on identification and assessment of potential risks and elimination of unaccepted risks. A safety management system (SMS) contains a number of elements including safety policy, job hazard analysis and safety and health awareness etc. This provides guidance for enterprises to manage risks and improve their safety and health performance. A SMS facilitates occupational safety and health management by providing systematic approaches for continual identification, evaluation and control of hazards and risks (Rondinelli and Berry, 2000).

Ahasan (1993, 1994, 2000b), Khan (1994, 1997, 2000) and Raihan (1997) have investigated many industries in Bangladesh and found that the majority of them do not have a long-term stake in environmental and climatic considerations. Some others (Fariduddin *et al*., 1975; Rahman, 1993; Ahmad *et al*., 1997; Sadeque *et al,* 1998) surveyed different workplaces in Bangladesh and analyzed local workers' energy expenditure, and health, safety and ergonomic issues. Rahman *et al*. (2000) expressed concern about using injury information for injury surveillance at the local level in Bangladesh. From these studies, it has been proven that workers usually worked long hours in unsafe conditions without using any personal protective devices (PPDs), for instance. Therefore, most of the workers' health, safety and well-being were deteriorating. It is also well known that the present status of Occupational Health and Safety/ ergonomics is still at the rudimentary level in Bangladesh because the factory owners (FO) and employers' associations (EA) usually consider these elements a costly luxury. It is also true that they usually lack money, resources and other elements to provide improved health and safety facilities to all the workers. In Bangladesh, field surveys and workplace inspections are conducted, however, only a few such studies and research have been conducted based on in-depth case studies. Workers' physical workload, heat stress and thermoregulatory related studies were conducted (Ahasan *et al*. 1997), but those studies do not contain all types of empirical data and ergonomic information. Some anthropometric data of female garment workers (Khan 1997) and other work-related information can be found in a few studies (Sadeque *et al*., 1997; Ahasan *et al*., 1997d,e; Ahasan *et al*., 1998b). Other studies have highlighted female workers' economic, social and health aspects (Rahaman *et al*., 1991; Majumder & Chowdhury, 1992; Zohir & Majumder, 1996). These studies may contribute some data and information, but they do not emphasize the practical importance of OHS and ergonomic applications.

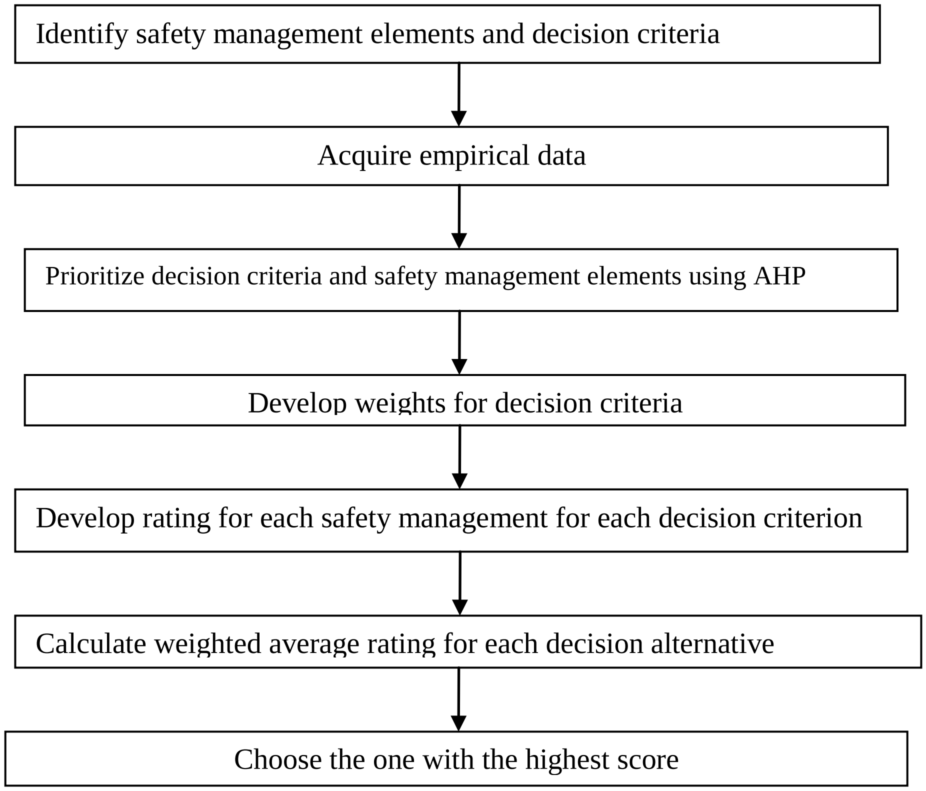
There is a pressing need to investigate the current industry situation in safety and health management and identify decision criteria for determining the implementation priority of safety management elements for manufacturing industries of Bangladesh. This research aims to present a hierarchy decision model for assessing the priority of safety management elements. Using the Analytical Hierarchy Process (AHP) methodology, the model addresses the identification of relative importance of decision criteria and safety management elements with respect to the effective SMS implementation in manufacturing enterprises.

2. Objectives

The objective of the present work is to study how the tools and techniques of the Analytical Hierarchy Process (AHP) can be applied to implement a Safety Management System in a manufacturing company in Bangladesh. To conduct the study, industrial hazards and several safety elements will be identified. Then, depending on the importance given by the industrial professional safety management elements, the elements will be prioritized using the Analytical Hierarchy Process (AHP).

3. Methodology

In order to investigate the relative priorities of the safety management elements for a manufacturing company, empirical data will be collected. From this information, an Analytical Hierarchy Model will be developed to prioritize safety management elements. The methodology will be as follows: (1)Identification of safety management elements and decision criteria most important to an effective safety management system using OSHA (Occupational Safety and Health Act) and NIOSH (National Institution for Occupational Safety and health) standards; (2)Acquisition of empirical data from personal interviews with evaluators such as safety personnel, experts and professionals in the industry who can evaluate the importance of decision criteria and safety management elements with respect to the corporate goals, resources and constraints in their organizations; (3)Formulation of an Analytical Hierarchy Model based on the evaluation to prioritize safety management decision criteria and relative importance of safety management elements. The process is summarized in the flowchart below.



4. Conduct of an AHP study

A list of attributes is generated and consolidated once AHP is confirmed as an appropriate solution method. AHP offers a two-stage process to cope with the complexity of the problem. The first of these two stages involves hierarchy construction. The attributes are organized in a hierarchy-type structure that reflects their mutual relationships. The primary goal of the research occupies the highest level of the structure, followed by “sets of attributes,” which are organized in several more hierarchy levels. A typical second-level attribute set includes all of the secondary goals that together contribute to achieving the primary goal. The purpose of this study was to determine the priority of decision criteria and elements for SMS implementation in manufacturing enterprises. To investigate the relative priorities of the safety management elements for manufacturing industries, the authors initiated a study in Bangladesh using the AHP methodology. The study involves the decomposition of a complex problem into a multi-level hierarchical structure of characteristics and criteria with the last hierarchical level constituting the decision alternatives. AHP can accommodate both objective and subjective judgments of the evaluators involved in order to make trade-offs and determine priorities among them. The goal of SMS implementation was decomposed into six criteria identified from interviews with industrial personnel. These criteria are: (1) client requirement, (2) employee requirement, (3) insurance company requirement, (4) cost effectiveness, (5) effect on production rate, and (6) expertise requirement. A group of five industry experts were interviewed to evaluate these criteria and elements. The evaluators included two safety professionals, two manufacturing specialists, and one top level manager. After the evaluation of these criteria ten safety management elements were evaluated. These were collected from the safety manuals of different manufacturing industries of Bangladesh. These elements are: (1) safety organization, (2) safety policy, (3) safety training, (4) in-house safety rules, (5) personal protection program, (6) accident/incident investigation, (7) emergency preparedness, (8) safety committee, (9) job hazard analysis, and (10) occupational health assurance program. These are shown in Table 1.

Table 1
Ten safety management elements

Safety Elements	Definition
Safety management elements	Normalized weight
Safety organization	A hierarchy that ensures effective implementation of safety and health at work place.
Safety policy	A legal requirement for an employer to prepare, and keep a written, up-to-date statement of their policy regarding the health and safety of their employees.
Safety training	Training to make the employees competent in health and safety.
In-house safety rules	Rules for achieving safety management objectives.
Personal protection program	A program to learn about standard precautions to prevent skin and mucous membrane exposure when in contact with blood and body fluids.
Accident/incident investigation	A process to determine the cause or causes of an accident or series of accidents so as to prevent further incidents of a similar kind.
Emergency preparedness	The capability that enables an organization or community to respond to an emergency in a coordinated, timely, and effective manner to prevent the loss of life and minimize injury and property damage.
Safety committee	Committee composed of medical, dental, nursing, engineering, administrative, and other staff members whose purpose is to oversee safety practice.
Job hazard analysis	Analysis that can be used to define and control the hazards associated with a certain process, job or procedure.
Occupational health assurance program	Development and maintenance of health awareness in a work place.

Weights of individual elements are compared and their respective priorities are obtained. Inconsistency ratios are calculated to verify the consistency of the comparison process.

5. Analysis and results

5.1 Evaluation of decision criteria

The industrial personnel have made pair wise comparison of decision criteria. From their evaluation a single pair-wise comparison matrix is developed which is shown in Table 2.

Table 2
Empirical data collection for decision criteria

Decision criteria of SMS Implementation	Client require-ment (a_1)	Employee require-ment (a_2)	Insurance require-ment (a_3)	Cost effective-ness (a_4)	Effect on product-ion rate (a_5)	Expertise require-ment (a_6)
Client requirement(b_1)	1	1/3	3	1/3	1/5	1
Employee requirement(b_2)	3	1	7	1	1/3	7
Insurance requirement(b_3)	1/3	1/7	1	1/9	1/9	1/3
Cost effectiveness(b_4)	3	1	9	1	1/3	5
Effect on production rate(b_5)	5	3	9	3	1	7
Expertise requirement(b_6)	1	1/7	3	1/5	1/7	1
Col. Sums	y_1=13.33	y_2=5.62	y_3=32	y_4=5.64	y_5=2.12	y_6=21.33

Then multiplying the values in each row together and calculating the nth root of said product normalizing the aforementioned nth root of products to get the appropriate weights and calculating and checking the Consistency Ratio (CR) which is shown below.

Geometric mean for client requirement $g_1 = (a_1b_1*a_2b_1*a_3b_1*a_4b_1*a_5b_1*a_6b_1)$ ^ (1/n)
= (1*1/3*3*1/3*1/5*1) ^ (1/6)
= 0.64197

Normalized weight for client requirement $x_1 = \frac{g1}{\sum_{i=1}^{6} gi}$
$= \frac{0.64197}{8.92}$
= 0.07197

Consistency index, C.I $= \frac{\lambda max - 6}{6-1} = 0.05332$

Where $\lambda max = y_1x_1 + y_2x_2 + y_3x_3 + y_4x_4 + y_5x_5 + y_6x_6 = 6.26661$

From Saaty's table, the randomly generated consistency index R.I. (for n=6) = 1.24

The consistency ratio, C.R = $\frac{C.I}{R.I}$

$= \frac{0.05332}{1.24}$

$= .043$ or, $4.3\% < 10\%$;

So, the decision criteria in terms of C.R are acceptable.

From the above calculation, the final normalized weights and priorities of the decision criteria for SMS implementation are shown in Table 3.

Table 3
Weights and priority of decision criteria for SMS implementation

Decision criteria of SMS Implementation	Normalized weight	Priority
Client requirement	0.07197	4
Employee requirement	0.21445	2
Insurance requirement	0.02711	6
Effect on production rate	0.42176	1
Cost effectiveness	0.21142	3
Expertise requirement	0.05382	5

Consistency ratio = 0.043

The top three criteria are identified as Effect on production rate, Employee requirement and Cost effectiveness.

5.2 Evaluation of safety management elements

A pair-wise comparison matrix for each criterion, with each matrix containing the pair-wise comparisons of the performance of safety management elements on each criterion is developed. This is done by multiplying the values in each row together and calculating the nth root of said product, normalizing the aforementioned nth root of product values to get the corresponding ratings. These pair-wise comparison matrices are shown in Tables 4-9.

Table 4
Weights evaluation of safety management elements with respect to client requirement

Safety management elements	Normalized weight
Safety organization	0.32
Safety policy	0.15
Safety training	0.07
In-house safety rules	0.04
Personal protection program	0.04
Accident/incident investigation	0.02
Emergency preparedness	0.04
Safety committee	0.14
Job hazard analysis	0.12
Occupational health assurance program	0.07

Table 5
Weights evaluation of safety management elements with respect to employee requirement

Safety management elements	Normalized weight
Safety organization	0.04
Safety policy	0.02
Safety training	0.06
In-house safety rules	0.06
Personal protection program	0.27
Accident/incident investigation	0.10
Emergency preparedness	0.17
Safety committee	0.02
Job hazard analysis	0.10
Occupational health assurance program	0.17

Table 6

Weights evaluation of safety management elements with respect to insurance requirement

Safety management elements	Normalized weight
Safety organization	0.07
Safety policy	0.21
Safety training	0.06
In-house safety rules	0.17
Personal protection program	0.12
Accident/incident investigation	0.03
Emergency preparedness	0.05
Safety committee	0.18
Job hazard analysis	0.03
Occupational health assurance program	0.08

Table 7
Weights evaluation of safety management elements with respect to effect on production rate

Safety management elements	Normalized weight
Safety organization	0.18
Safety policy	0.10
Safety training	0.03
In-house safety rules	0.08
Personal protection program	0.17
Accident/incident investigation	0.04
Emergency preparedness	0.18
Safety committee	0.03
Job hazard analysis	0.10
Occupational health assurance program	0.10

Table 8

Weights evaluation of safety management elements with respect to cost effectiveness

Safety management elements	Normalized weight
Safety organization	0.13
Safety policy	0.18
Safety training	0.05
In-house safety rules	0.18
Personal protection program	0.06
Accident/incident investigation	0.06
Emergency preparedness	0.12
Safety committee	0.03
Job hazard analysis	0.08
Occupational health assurance program	0.12

Table 9
Weights evaluation of safety management elements with respect to expertise requirement

Safety management elements	Normalized weight
Safety organization	0.04
Safety policy	0.20
Safety training	0.13
In-house safety rules	0.09
Personal protection program	0.03
Accident/incident investigation	0.09
Emergency preparedness	0.05
Safety committee	0.17
Job hazard analysis	0.14
Occupational health assurance program	0.06

The composite weight for each safety management element is calculated by summation of the products of each decision criterion and safety management element. The overall implementation priorities of individual elements are determined by combining the element evaluation results against criteria from the final evaluation of safety management elements which is shown in Table 10.

For an example, the composite weight for Safety organization is computed as follows:

$$0.07197*0.32+0.21445*0.04+0.02711*0.07+0.21142*0.13+0.42176*0.18 +0.05*0.04 = 0.13906$$

Table 10
Overall weights evaluation of safety management elements

Safety management elements	Client require-ment (0.072)	Employee require-ment (0.214)	Insurance require-ment (0.027)	Cost effectiveness (0.211)	Effect on production rate (0.422)	Expertise require-ment (0.05)	Composite weight	Overall ranking
Safety organization	0.32	0.04	0.07	0.13	0.18	0.04	0.139	3
Safety policy	0.15	0.02	0.21	0.18	0.10	0.20	0.112	5
Safety training	0.07	0.06	0.06	0.05	0.03	0.13	0.050	9
In-house safety rules	0.04	0.06	0.17	0.18	0.08	0.09	0.097	7
Personal protection program	0.04	0.27	0.12	0.06	0.17	0.03	0.150	1
Accident/ incident investigation	0.02	0.10	0.03	0.06	0.04	0.09	0.058	8
Emergency preparedness	0.04	0.17	0.05	0.12	0.18	0.05	0.145	2
Safety committee	0.14	0.02	0.18	0.03	0.03	0.17	0.047	10
Job hazard analysis	0.12	0.10	0.03	0.08	0.10	0.14	0.098	6
Occupational health assurance program	0.07	0.17	0.08	0.12	0.10	0.06	0.114	4

The top three safety management elements for battery industries are identified as (1) Personal protection program, (2) Emergency preparedness, and (3) Safety organization.

6. Conclusion

Safety Management Systems (SMS) is a term used to refer to comprehensive systems designed to manage the safety, health, environmental and general risk aspects of an industry. An SMS is the specific application of quality management to safety. Safety management systems (SMS) help companies identify safety risks before they become bigger problems. The Safety Management System approach moves beyond the traditional reactionary system to one which tries to predict areas of exposure. This is done through assessment of any residual risk areas in airworthiness and operations, and then supplementing these with operational knowledge and professional judgment. Therefore, SMS implementation provides guidance for manufacturing enterprises in managing and improving safety and health performance. The ultimate goal is to implement, as far as possible, the applicable safety management elements in order to maximize the effectiveness of improving safety and health performance. However, to implement all or most elements concurrently is impractical especially for small and medium enterprises. Therefore, the priority of implementation can be determined for manufacturing enterprises so that they can focus their resources on fewer elements at a time. Industrial personnel can evaluate the relative importance of safety management elements with respect to the corporate goals, resources and constraints of their respective organization using the Analytical Hierarchy Process. The top three elements for battery industries were identified as (1) personal protection program, (2) emergency preparedness, and (3) safety organization. Interestingly, though safety policy is a vital element for SMS implementation it ranked fifth place. The evaluators were mainly concerned about individual safety rather than hazard source identification and removal.

In this paper a hierarchy decision model was established to prioritize safety management elements for battery manufacturing industries. It will help industries to determine these elements in the design, establishment and implementation of their SMS. An effective SMS will provide a means of achieving enhanced safety performance which meets or exceeds basic compliance with the regulatory requirements associated with safety and quality. It is a well-established fact that enhanced safety performance is founded upon a proactive safety culture inherent in all the organization's safety related activities.

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