Environmental Ergonomics: An Introduction of Principles, Methods and Models for the Assessment of Health, Safety, Environment and Ergonomics in a Petrochemical Industry

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Abstract—*A brief review of the principles, methods and models used in environmental ergonomic for the assessment of health, safety, environment and ergonomics in a petrochemical industry. It is achieved through integrating ergonomic and macro-ergonomics as well as occupational health and safety arrangements in an integrated modeling for assessment of their multi-faceted impact on worker' productivity, injury rate and satisfaction. Various methodologies like FCM, DEA, Taguchi, are applied in an integrated manner. Environmental ergonomics is an integral part of the discipline of ergonomics and should be viewed and practiced from that perspective. Humans do not respond to the environment in a monotonically related to direct measures of the physical environment. The outcomes will certainly help managers to have better understanding of weak and strong points in terms of HSEE factors. Ergonomics can be actively significant within the organization on issues relating to work enhancements; it may boost integrated increases in the organization's enactment and in workers' well-being; it can provide provision for modifications and new sustainable work requirements and it can contribute to the concept of work in a context of sustainable development.*

Keywords: *Ergonomics; HSEE factors; Generation industry.*

1. INTRODUCTION

The application of knowledge of human characteristics to the design of systems, defined as "Ergonomics" has become a well-defined term to the general public, with its use in marketing campaigns to denote quality of design and user friendly submission [1,2]. Ergonomics can be defined as the application of knowledge of human characteristics to the design of systems. People in systems operate within an environment and environmental ergonomics is concerned with how they interact with the environment from the outlook of ergonomics. Although there have been many studies, over hundreds of years, of human responses to the environment (light, noise, heat, cold, etc.) and it is only with the development of ergonomics as a discipline that the unique features of environmental ergonomics are beginning to develop[3].

In principle, environmental ergonomics will incorporate the social, psychological, cultural and organizational environments of systems. Typically, ergonomists have considered the environment in a mechanistic way in terms such as the lighting or noise survey rather than as an integral part of ergonomics investigation. The establishment of the study of human responses to the physical environment has inconsistently repressed the progress of environmental ergonomics.

Table 1: HSEE factors [3]

Category	Factor
Health	1. Number of periodic examinations 2. Preemployment medical examination to number of employed 3. pH: water
Safety	1.Accidient frequency rate 2. Sevier accident rate 3. Fatal accident rate
Environment	1. Energy utilization
Ergonomics (Microergonomics) Ergonomics (Macroergonomics)	1. Light intensity at working place 2. Skeletal disorder rate 3. Noise level 4. Lifting Index 1. Availability 2. Reliability

Health, safety, and environment and ergonomics (HSEE) at the operational level will strive to eliminate injuries, adverse health effects, and damage to the environment. Effective application of ergonomics in work system design can achieve a balance between worker characteristics and task demands. In an industrial setting, management commitment and employee involvement are critical for the success of any ergonomics program [4-6]. This can enhance worker productivity, provide improved worker safety (physical and mental), and job satisfaction. Several studies have shown positive effects of applying ergonomics principles to the workplace including machine, job, and environmental designs [7,8]. The brief introduction of ergonomics program approach described in this paper, although developed for the large manufacturing environment, can be applied to any-size industry.

2. METHODOLOGY FOR ENVIRONMENTAL ERGONOMICS

There are basically four key methods generally involved for the assessment of the human response to the environment. These are – *subjective, objective, behavioral, and modeling methods* [5].

The *subjective methods* include the discourse analysis, thermal responses, and questionnaires and have the advantage of being relatively easy to carry out particularly suitable for the psychological responses like comfort and annoyance but are difficult to design having a number of potential methodological biases. Also they are often not sufficient for the assessment of the matters like ill effects onto the health and environment and often require the use of a representative sample of the user population being exposed to the environment of interest. This method is burdensome if used in initial design.

Objective methods have the advantage of providing direct measures of human response includes measures of body temperature, transmitted acceleration as well as direct measures of performance at a task. The main disadvantages are that a representative sample of the user population is required to be exposed to the environment of interest.

Behavioral methods are probably very little used in environmental ergonomics. They can have the unique advantage of not intrusive with what they are attempting to quantify, includes changes in posture, changing clothing, adjusting the environment, moving away, working faster or slower, and so on. These methods are particularly suited for studying some people with disabilities, children, or other special populations. The only difficulty is in determining the cause and effect.

Models of human response to environments have the advantage of being consistent in their response, are easy to use, give a quick response and can be used in both design and evaluation. The main disadvantages are that the models provide only approximate responses when designing for individuals. In most practical applications the ergonomist will use a combination of the methods.

Table 2: Summary of cognitive principle and recommendations [4].

Cognitive Concepts	Recommendations
Responsibility	1. Instill a sense of personal control of the solution by designing products with interactive curtailing features.
Complex Decision-making Skills	2. Constrain customers' product decisions with industry standards. 3. Encourage tackling of complex decisions through interaction incentives and designed-in educational feedback
Decision Heuristics	4. Address the customers' environmental concerns as well as the crucial environmental issues 5. Identify useful heuristics and use them to educate about the product's environmental impact 6. Identify perceptual product cues that communicate environmental impact
Altruism- Sacrifice Link	7. Offer only "triumphs" and downplay altruism in the product's design 8. Apply design for upgradability or adaptability to work-horse products that are known for reliability and are not status symbols
Trust	9. Design trust into the product's form using semantics and heuristics 10. Design trust into the product's interactions using similarity
Cog, Dissonance and Guilt	11. Avoid making customers feel guilty
Motivation	12. Change PEB motivation from extrinsic to intrinsic with small, well-timed incentives designed into product interactions 13. Work with policy makers/ marketers to design eco-product purchase incentives 14. Design eco-products for ease of use 15. Design product with social norms in mind.

3. HSEE MODELS

There are various kinds of models for the HSEE. Three of them namely, Fuzzy Cognitive Map (FCM) methodology, Data envelopment analysis (DEA) and Taguchi method have been described in brief here.

3.1. Introduction to FCM

Fuzzy Cognitive Map (FCM) methodology is a emblematic representation that is used for relating and modeling complex systems, provide excellent mechanisms for supporting decision-makers. These decisions may result in either positive or dramatic consequence that depends on the correct evaluation decisional factors. FCMs provide decision makers with a tool to support and make successful decisions. It incorporates the accumulated experience and knowledge by employing human experts who are aware of system operations and behavior in different situations. The main advantage of this method is its simplicity and it functions on expert's opinion [3].

FCM describe the behavior of an intricate arrangement which represent different states, characteristics, or variables of the system. These concepts interact with each other in order to show the dynamics of the system. FCM illustrates the whole system by a graph showing the cause and effect relations that exists among these concepts.

With the current increasing need for safety, productivity and efficiency of both plant and human operator, fuzzy cognitive maps (FCM) will provide an organization with a valid help in assessing the most critical factors in managing socio-technical system, providing an interesting solution for assessing the factors which are considered to affect the operator's safety, productivity and satisfaction.

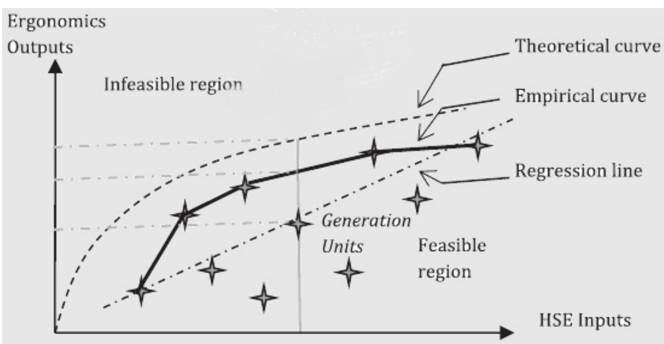

Fig. 1: Frontiers of data envelopment analysis for generation companies with respect to health, safety, and environment (HSE) and ergonomics [8].

3.2. Data envelopment analysis (DEA)

It refers to the individuals in the evaluation group. The DEA generates a "frontier" that follows the peak performers and envelops the remaining. Fig. 2 demonstrates absolute maximum possible production that a DEA can achieve in any level of input. However, the theoretical relationships between input and output parameters of a system are generally difficult to identify and to express mathematically. That is why the theoretical frontier is generally unknown. Therefore, the relative or empirical frontier based on real DEA is used.

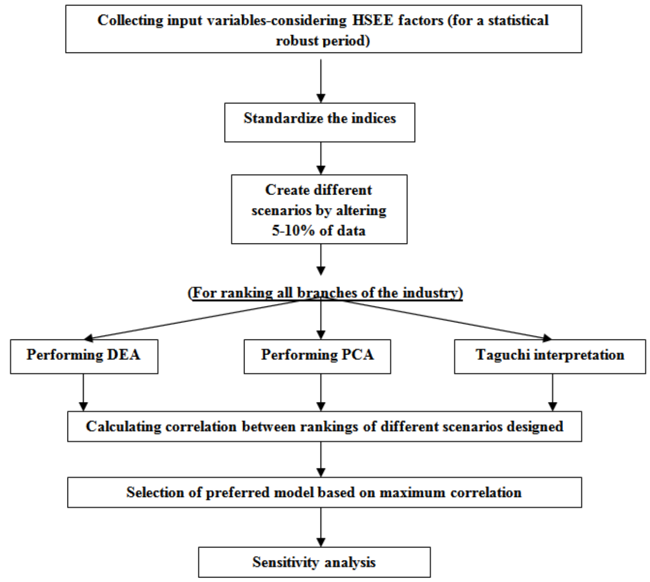

Fig. 2: Structure of the proposed approach: (DEA-data envelopment analysis; HSEE- health, safety, environment and ergonomics; PCA-principal component analysis) [8]

3.3. Taguchi method

This statistical approach, Taguchi method, is mainly used for dealing with the constraint of the factorial and fractional factorial experiments. It reduces and standardizes the fractional factorial design. *Azadeh A.* (2015) used the Taguchi loss function for ranking different scenarios. In this procedure, the Taguchi loss function is used to develop a single objective function in a multi-criteria problem. For each criterion, actual loss will be calculated using Equation 1 and will fall between 0% and 100% loss.

$$L = kx^2 \tag{1}$$

where k is calculated as follows:

$$k = \frac{100\%}{(USL)^2} \tag{2}$$

where L is the loss generated for each criterion, x is the characteristic measurement, USL is the upper specification limit, and k is a constant calculated to return 100% loss at the specification limit. This formulation is used for input criteria. For output criteria, the data must be inversed.

4. CONCLUSION

From the above discussions it can be concluded that the models for the health, safety, environment and ergonomics (HSEE) has a great relation with the effects of light, noise, vibration, and thermal environments on the health, comfort, and working efficiency of the occupants of buildings. Models exist which can provide realistic predictions of the effects or probable effects of components of environments. Moreover, fundamental acquaintance is still required on environmental interactions.

The direct and indirect effects of HSEE factors on each other as well as on system performance indicators were assessed. FCM, DEA and Taguchi method's result were used to develop leading indicators for the positive management of system performance. Future developments in this area should lead to greater predictive power of these models. The development of computer software will allow the models to become readily available to those who wish to design and evaluate buildings.

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