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Integrated Health, Safety, Environment and Ergonomic Management Systems for Industry

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Abstract

Background: Conventional health, safety and environment (HSE) are a widely used approach to enhance availability and efficiency of complex systems. The integrated HSEE system is defined however as integration of conventional HSE with ergonomics approach. The presented HSEE system introduces a unique, effective and systemic mechanism, which integrates the structure of the human and organizational systems with conventional HSE system. It is utilized to enhance reliability, availability, maintainability and safety through the proposed integrated framework of this study.
Methods: The integrated HSEE is developed by integration of conventional HSE with job systems by re-engineering organizational structures and teamwork through electronic data interchange (EDI). To show the need for and superiority of HSEE over conventional HSE to gas Treatment Company was studied and questionnaires were collected and examined with respect to distinct components of HSEE.
Results: The main result of this study is a framework for development of integrated intelligent human engineering environment in complex critical systems.
Conclusion: The presented HSEE system introduces a unique, effective and systemic mechanism, which integrates the structure of the human and organizational systems with conventional HSE system.

Keywords: *Health, Safety, Environment, Ergonomics, Integrated*

Introduction

To be successful in losses prevention an organization must construct a solid foundation from which to build (1). This foundation is built by the organization's clear vision of the future and the specific means by which it will get there through the achievement of the mission (2). As a shared principle of "how we do business within this organization", a healthy corporate culture is based on positive and respectful values, principles, and beliefs towards safety, health and the interaction with the environment (3). In successful organizations, this culture is evidenced throughout all business strategies reflecting an integrated approach and philosophy. By establishing and integrating these fundamental themes into a common managed system, organizations will then be able to build meaningful standards and applied procedures/ practices resulting in the reduction/elimination of injury causes, losses to the environment, property, process, equipment, materials, as well

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as personal injuries and adverse health effects (4).

A review was undertaken to analyze major international and national standards and codes, and IRAN legislative requirements. In addition, a literature review of relevant safety, health and environment (HSE) organizational best practices and managing systems was completed. Based on these reviews and experience obtained from Iran Petroleum Ministry and Iran Energy Ministry professional staff working with organizations, it was realized that safety, health and environment systems required a continual and systematic managed effort in order to achieve sustainable success. It was found that key HSE organizational success components included (but not limited to) the following:

• Successful organizations have a common set of fundamental values, beliefs and principles that are integrated into all organizational business strategies.

• Legislative requirements reflect minimum standards only.

•The protection of safety, health of workers, clients, community and environment are fundamental to organizational culture.

• SH&E requires a continuous improvement process and integrated managed system.

• Organizations are required to possess the internal capacity to successfully sustain a system for continuous improvement and integration of SH&E.

Safety Management Discipline

The principles of safety management are applied to activities that identify and quantify the risk of personal injuries and all types of property damage in the workplace (5). The safety management discipline consists of the following elements (6): General rules, behavior based performance, work permits, general promotion, product safety, fleet safety, off the Job safety, workplace violence, and security.

Health Management Discipline

Health management represents a vital discipline within a successful safety, health and environmental management system. The aim of a health management system is to anticipate, recognize, evaluate and control all health hazards in the work environment and to provide appropriate resources for the overall health and wellness of all workplace parties (7).

Environmental Management Discipline

An environmental management system provides the framework for an organization to achieve and sustain performance in accordance with established goals and in response to constantly changing regulations, social, financial, economic and competitive pressures related to environmental risks (8). The environmental management subject discipline contains the elements of waste management for both hazardous and non-hazardous waste, Pollution Prevention for air, water, soil, and ground water, and community involvement as for flora, fauna and humans.

Ergonomics

Traditional human engineering techniques are concerned with improving the interface design between human operators and machines. However, without its upward integration with job of operators and organizational design of such systems, at best, it leads only to sub-optimization and, therefore, results in an inherently error- and failure-prone total system. Such a system, eventually, when faced with concatenation of certain events, would suffer from this `resident pathogen (9, 10). In fact, operators' error should be seen as the result of human variability, which is an integral element in human learning and adaptation (11). Thus, human error occurrences are defined by the behavior of total human-task-organizational system. In addition, this integration must be designed in context of the new information technology.

Finding the mechanisms, which optimize the teamwork between operators, machines and organization, is one of the great technological challenges of the twenty-first century (12). The technological challenge is to create an intellectual interface between human operators, machines, safety, environmental issues and organizational structures. In fact, organizational errors are often the root causes of human errors and man-machine failures (13, 14). In addition, the interface systems must be matched with operators' capabilities. Therefore, there is a need for an integrated design between health, safety, environment and ergonomics (HSEE). Furthermore, it has been shown that the integration of HSEE in context of information technology and integration of job design and organizational design in the context of re-engineering will enhance the reliability and productivity of manufacturing systems (15). To this end, the concept of re-engineering is discussed in the next section.

Intelligent Ergonomics

As mentioned, ergonomics strives to optimize the interaction between human operator and machine. In an intelligent ergonomics approach, the usability and ergonomics factors in parallel to the organizational and HSE aspects of working conditions in context of a total system approach are considered. Moreover, it attempts to create equilibrium between, organization, operators and HSE through the utilization of electronic data interchange (EDI), usability design and reengineering. It focuses on overall "people-technology-HSE" systems and is concerned with the impacts of technological systems on organizational, HSE and personnel sub-systems.

The present complex technological systems pose additional demands and new requirements on the human operators. The role of human operators responsible for such systems has changed from man-in-the-loop, controller to a "supervisory controller" who is responsible for overseeing one or more computer controllers who perform the routine, frequently occurring control functions. In supervisory control systems, the human operator's role is primarily passive, a monitor of the change in system state (16). Unfortunately, the operators may suffer from isolation and remoteness from actual work. They may find their skills degraded when called upon to take over emergencies. Therefore, in an intelligent ergonomics environment, the interface systems must be matched with operators' capabilities and HSE. Decision styles model is an ideal tool for assessing coordination and creating a match between operators and machines (interfaces). This model suggests that environmental load systematically affect the complexity of information processing in persons in an inverted-U-shape function (17).

In addition, there is a need to create an intelligent interface between human operators and machines. An intelligent interface system is capable of adjusting itself with evolving information technology through usability engineering and design techniques. The interface design should aim at making the boundaries of acceptable performance visible to operators while the effects of the committed errors are observable and reversible (18). To assist the operators in coping with unforeseen situations (health, safety and environmental issues), the interface design should provide them tools to make experiments and test hypothesis without having to carry them directly on potentially irreversible processes.

The Systems View of Integration

The need to apply systems thinking to the introduction of the ISO 9000 series (19) and to the integration of standards and performance measurement, has led to a number of useful suggestions, some of which are based on Beer’s (20) concepts. It helps users to see the relationship between the elements of the standards that make up the QMS, EMS, OH & SMS etc., and how they fit into the overall management and business systems. “Linking two systems in a way that results in a loss of independence of one or both means that these systems are integrated.” The integrated systems then form a “system of systems” where the individual systems retain their identity. In addition to ensuring customer satisfaction and loyalty, organizations must consider the well-being of their employees and the working environment, and the impact that their operations have on their neighbors and the local community.

The main goal of this study is present a framework for development of integrated intelligent human engineering environment in complex critical systems.

Materials and Methods

Since a complex system involves a variety of disciplines, the managers must be alert of critical problems falling between disciplines. Moreover, the managers of such systems must utilize an integrated method to identify the gaps at interfaces and overlooked weak points. To facilitate this integration, we attempt to minimize the distance between the operators and the decision-makers. The greater the distance between the operators and the decision-makers, the more complex the communication and the higher the level of uncertainty and insecurity. Re-engineering used for system integrating. Re-engineering is the collection of activities and mechanisms required changing from hierarchical to horizontal, flat and cross-functional structures based on teamwork within an organization. The main goal in such program is internal and external customer's satisfaction. To present the importance of re-engineering in context of HSEE in complex manufacturing systems, HSEE system in Sarkhon and Qeshm gas treatment company-IRAN- were studied. Furthermore, maintenance and operation operators of the power plant were divided into two groups: operators who believe there could be a better job design and operators who believe the current system of job design are correct. The two groups were tested with respect to job pressures, which are defined as workload level, time considerations and stress. In addition, two groups of operators with and without inter-organizational issues and two groups of operators having and not having problems with organizational procedures were compared statistically. In addition, the same types of analysis were conducted in two other power plants and similar findings were obtained with respect to ergonomics but their results are not discussed here.

Kruskasl-Wallis test used to data analysis. It performs an analysis that is very similar to an analysis of variance (ANOVA) on the ranks. The test statistic is calculated using the following formula:

$$H = \frac{12}{N(N+1)} \sum \frac{T_i^2}{n_i} - 3(N+1)$$

N: total number of subjects

ni: number of scores in each of the two condition

Ti: total of the rank in each of the two conditions.

Results

An appropriate organizational structure is a main prerequisite for HSEE-management system implementation. Resulted re-engineering organizational structure was shown in Fig. 1.

The first test examines the differences between operators who receive on-the-job training and the ones who receive no on-the-job training in respect to the level of job pressures. From the results of Kruskal-Wallis through SPSS, it is concluded that there is significant difference between the two groups ($P< 0.05$) and the operators who receive no on-the-job training report higher level of job pressure (time and production pressures) by about 30%. The next test examines the previous two groups in respect to the quality of perceived information from supervisors. It is concluded that there is significant difference ($P< 0.10$) between the operators who receive on-the-job training and the ones who receive no on-the-job training in lieu of the quality of information they receive from the supervisors. Furthermore, the quality of perceived information from supervisors is higher for the operators who receive on-the-job training by about 30%. Also, the operators who received training related to accident mitigation and prevention and safety issues are compared with the ones who don't receive such training in regard to job pressures by the Kruskal-Wallis. The null hypothesis is rejected (*P*< 0.01) and it is concluded that there is significant difference (*P*< 0.05) between the two groups in respect to job pressures (production and time pressures). In fact, the operators who do not receive safety training report higher level of job pressure (by about 40%).

The difference between operators who are capable of locating non-routine (emergency at work with the ones who do not have this capability in relation to the quality of information they perceive from co-workers is examined. It is concluded that there is significant difference between the two groups in lieu of the quality of information they perceive from co-workers (*P*< 0.01). Operators who are capable of locating emergencies report higher quality of perceived information (about 45%) from co-workers. In addition, the operators who have problems using organizational procedures during routine situations are compared with the group who do not report any problems in respect to the quality of information they perceive from co-workers. The null hypothesis is rejected and it is concluded that the two groups of operators differ significantly (*P*< 0.10) in the quality of information they receive from co-workers. The operators who don't have any problem using organizational procedures report higher quality of perceived information from co-workers. Next, the same groups of operators were compared concerning the quality of information they perceive from supervisors. The null hypothesis was rejected (*P*< 0.01) and it was concluded that the ones who do not report any problem with organizational procedures also report higher quality of perceived information from supervisors by about 60%. The same two groups of operators are examined in lieu of job pressures and it is concluded that the operators who do not report any problem with organizational procedures also report lower level of job pressures by about 50%.

The operators who report problems with co-workers due to inter-organizational issues are compared the ones who don't have such problems due to inter-organizational issues in respect to the level of job pressures. The null hypothesis is rejected and it is concluded that the two groups differ significantly (*P*< 0.01)

The operators who believe there could be a better job design are compared with the ones who do not believe there could be a better job design in respect to the level of job pressures. The null hypothesis is rejected and it is concluded that the two groups differ significantly (*P*< 0.01). Moreover, the operators who believed that there could be a better job design reported higher level of job pressures (production and time pressures) by about 300%. The results of the tests are showed in Table 1.

Fig. 2 presents the design elements of intelligent ergonomics factors as a prerequisite for development of integrated HSEE. It is noticed that the prescribed approach is integrated rather than conventional and requires a systemic effort throughout organization.

To present the importance of information exchange in context of the integrated HSEE and consequently the importance of Electronic Data Interchange for such integrated design, the maintenance and operation operators of an Iranian gas company were studied by non-parametric statistical analysis. The Cramer's Phi statistic tests the null hypothesis (H0) of no correlation between the two variables against alternative hypothesis (H1) of correlation between the two variables (Table 3).

There is strong evidence that suitability (quality) of perceived information from co-workers and supervisors are correlated with job pressures. Lower job pressures are reported as the quality and usefulness of perceived information increases.

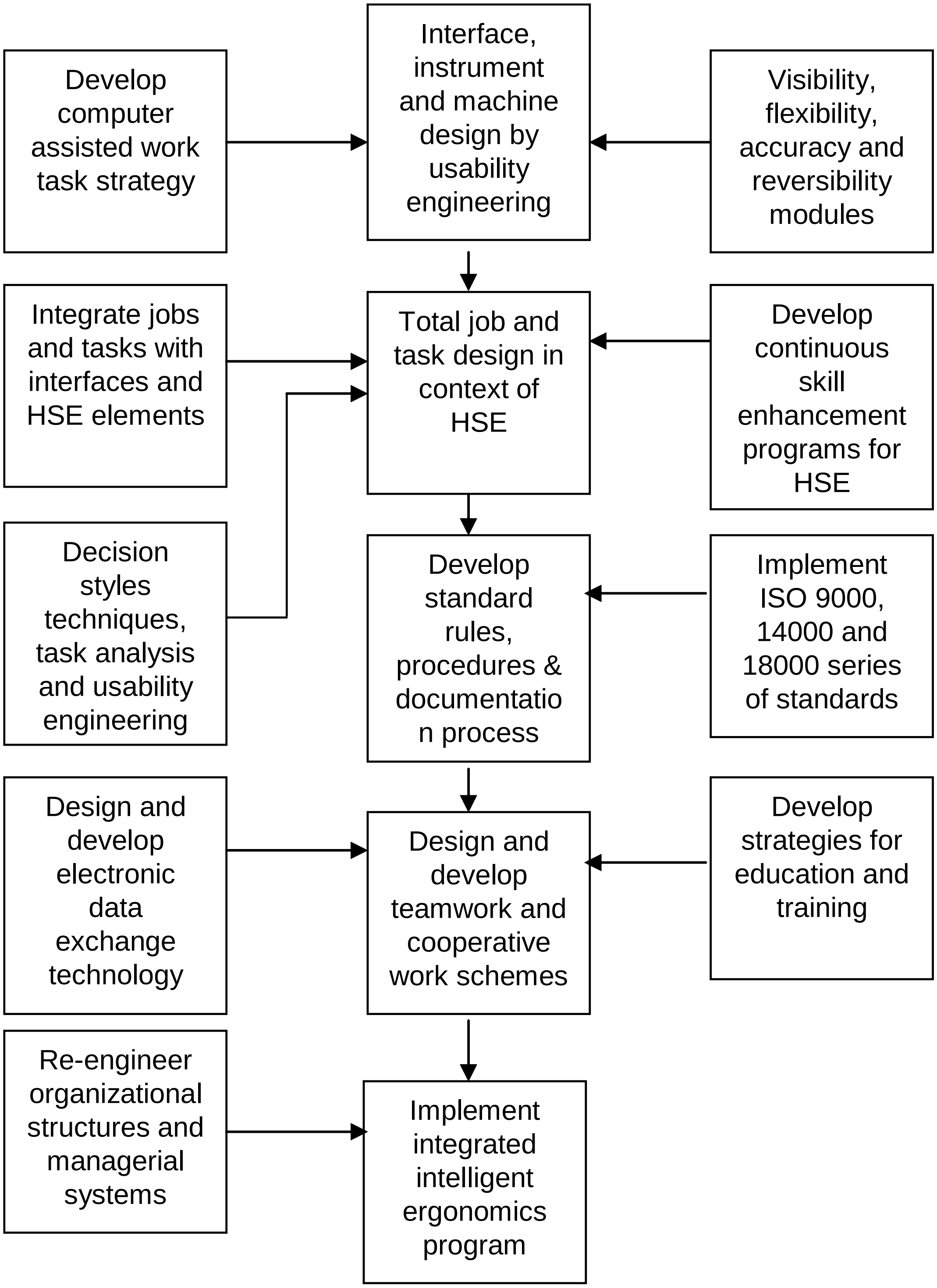

Fig. 1: Re-engineering organizational structures as a prerequisite for HSEE

Table 1: The results of Kruskal-Wallis test on difference on ranks

Difference in mean ranking of 2 groups of operators		Response variable	Significance level for rejection	Improvement in mean response ranking[1] (%)
Group I	**Group II**			
Operators with safety and accident prevention training	Operators with no training	Job Pressures	0.0100	40 (I)
Operators capable of locating emergency situations	Operators not capable of locating emergency situations	Quality of perceived information from co-workers	0.0694	45 (I)
Operators having problems with organizational procedures	Operators having no problem with organizational procedures	Quality of perceived information from co-workers	0.0609	40 (I)
Operators having problems with organizational procedures	Operators having no problem with organizational procedures	Quality of perceived information from supervisors	0.0003	60 (II)
Operators having problems with organizational procedures	Operators having no problem with organizational procedures	Job Pressures	0.0009	50 (II)
Operators having problems using procedures during emergency	Operators having no problem using procedures during emergency	Quality of perceived information from supervisors	0.0011	50 (II)
Operators who are rewarded for teamwork	Operators who are not rewarded for teamwork	Job Pressures	0.0030	70 (I)
Operators who are rewarded for teamwork	Operators who are not rewarded for teamwork	Quality of perceived information from supervisors	0.0041	40 (I)
Operators who violate safety procedures	Operators who don't violate safety procedures	Job Pressures	0.0054	50 (I)
Operators who can easily communicate with supervisors	Operators who cant easily communicate with supervisors	Job Pressures	0.0073	58 (II)
Operators with problems with co-workers	Operators with no problem with co-workers	Quality of perceived information from supervisors	0.0123	32 (I)
Operators believing a better job design is required	Operators believing current system is okay	Job pressures	0.0010	300 (I)

1: The Latin number in the parentheses indicate the group number

Table 2: Test of correlation between job pressures and selected ergonomics factors

Human engineering factors	Cramer's Phi	Significant Level (α)
1. Usefulness of informal information exchange	.43	.00017
2. Reward for teamwork by supervisors	.55	.00002
3. Supervisors' monitoring and assessment at work	.40	.00900

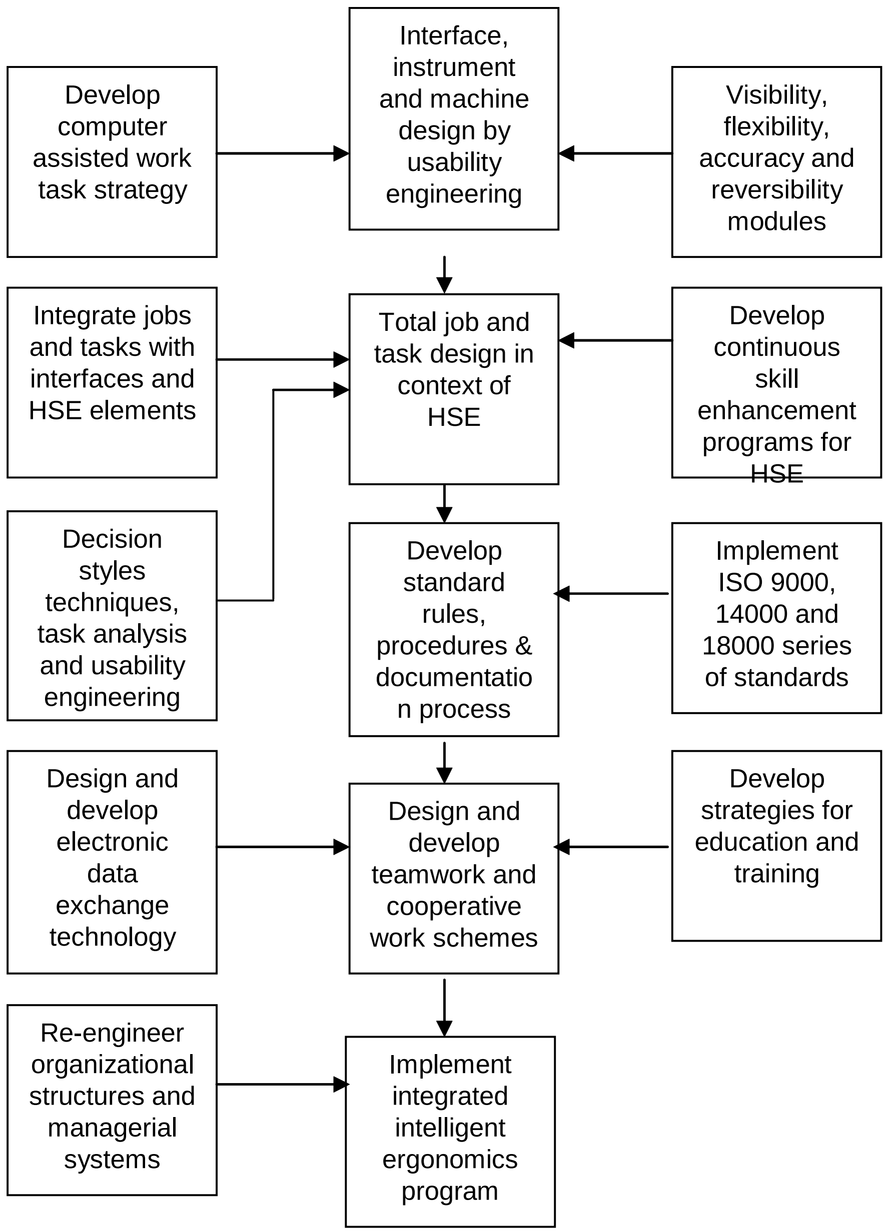

Fig. 2: The elements of intelligent ergonomics program in context of HSEE

Table 3: Test of correlation between job pressures and quality of information

TSD factor	Cramer's Phi	Significant Level (α)
1. Suitability of perceived information from supervisors	.56	.00000
2. Suitability of perceived information from co-workers	.45	.00008
3. Ease of contact with supervisors	.50	.00002

Discussion

The integrated HSEE-MS is defined as integration of conventional HSE-MS with ergonomics factors through electronic data interchange, teamwork and re-engineering organizational structures (Fig. 3). It is designed to enhance reliability, productivity and tolerance of manufacturing systems. Introduction of unmatched technology (both advanced and information technology) is the major bottleneck in design and implementation of an integrated HSEE-MS. Also, the specialization of designers and engineers of such systems adds a new magnitude of reservation. Most designers prefer to deal with absolutes than probabilities. The designers and engineers need to adopt a more holistic approach to problems of human systems. They must consider the whole and avoid the trap of dealing with specialties with which they feel comfortable.

Automated teamwork in context of electronic data interchange (EDI) technology, interface design in context of usability design, job design and organizational design in the context of re-engineering when integrated with conventional HSE-MS could enhance the reliability and productivity of manufacturing systems. However, it should be noted that each system is unique and the problem solving approach of each system must be based on systems uniqueness philosophy. Furthermore, the design philosophy of an integrated intelligent human factors engineering system must be based on sim-plicity and practicability.

Job design and organizational design in context of re-engineering requires assessment and redesign of all tasks, jobs, responsibilities, hierarchies, and communication channels within the organization. We need to create an HSEE new for the internal customers (personnel), external customers and organization itself by employing the concepts of ergonomics in the context of re-engineering. Two fundamental questions must be answered, first: what should our organization do to accomplish HSEE? And how it should be accomplished? Furthermore, previous experiences and activities with respect to HSE, job design and organizational design must be integrated with re-engineering concept and EDI to design and implement HSEE-MS. We showed the need for HSEE-MS through a real example in this paper. Furthermore, we showed that HSEE-MS is superior over conventional HSE-MS through identification of major problems with ergonomics factors in power plant. Moreover, we proposed an integrated HSEE-MS though integration of conventional HSE management system with job systems and re-engineering organizational structures and electronic data interchange technology.

Based on this study results, we can conclude that HSEE factors significantly influence human performance and therefore they must be considered and designed concurrently with the local factors in order to optimize human performance in particular and the system in general.

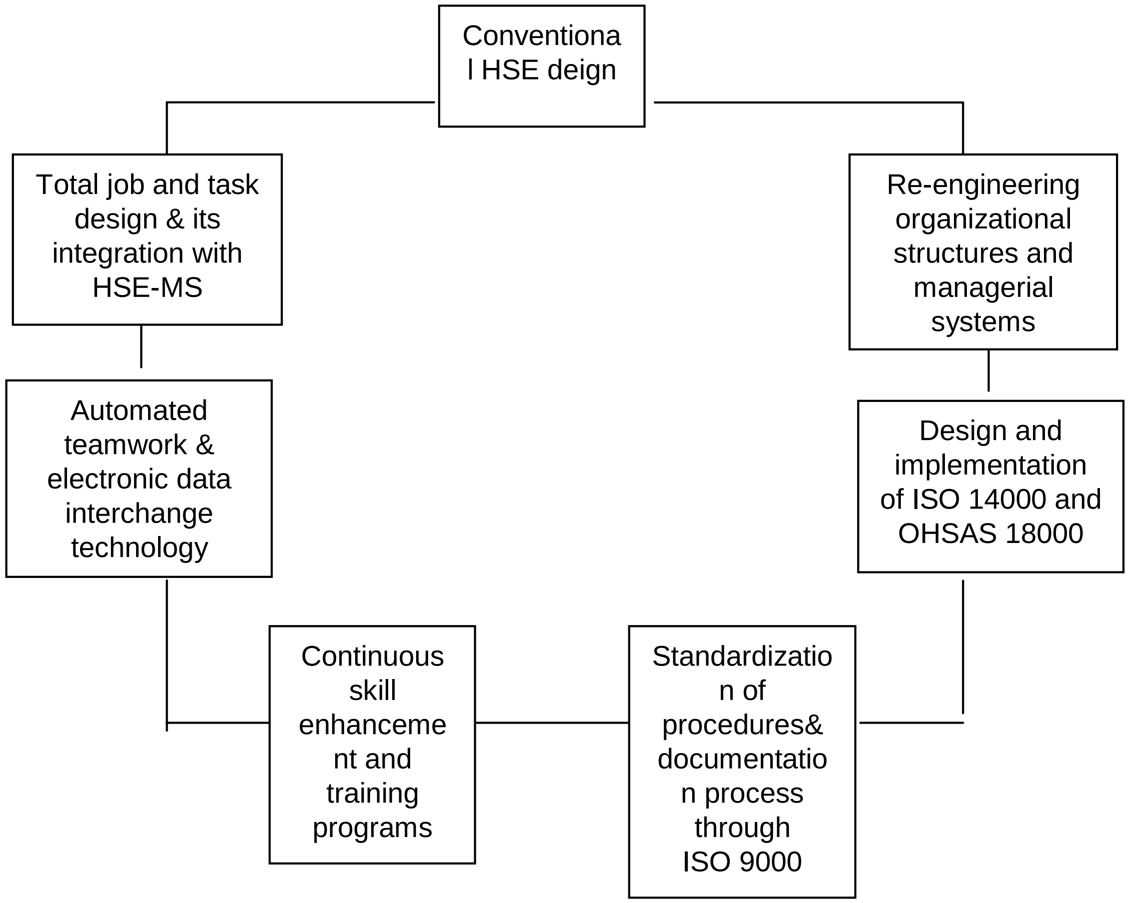

Fig. 3: Integrated health, safety, environment and ergonomics (HSEE)

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