

Original Article

Modeling an integrated Health, Safety, Environment and Ergonomic system for performance assessment

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ABSTRACT

Aims: The main goal of this study was to present a reference model for the Health, Safety, Environment and Ergonomic HSEE performance measurement system.

Materials And Methods: This study was done in a petrochemical unit in Iran during the year 2009. In first step, the existing information systems and their effect on personals were evaluated. Then the HSEE performance indicators were determined. The number of indicators were 244. After designing and implementing of the continuous monitoring system, the mentioned indicators were measured and controlled, continually.

Results: In cases that the indicators showed deviation from defined criteria, corrective actions can be done with forecasting and introducing some suitable techniques for hazard identification and problem solving. With implementation of the integrated performance measuring system unsafe behavior, musculoskeletal disorder and suitability of HSEE committee discussions were improved 12%, 7.3% and 22.6%, respectively.

Conclusion: The findings of this study emphasis on the need to conduct further research on the continuous monitoring of mentioned system in future years and performing necessary corrections. To improve the system performance, the continuous correction of indicators and related decision criteria, regular training of personal and implementation of award system are suggested.

Key words: Continuous improvement, environment, integrated system, performance, safety

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INTRODUCTION

Technological development is a result of a number of technological changes in goods production methods and service offering, the changes themselves being the result of the application of the newly acquired knowledge.^[1] Technological changes can be classified into a number of

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technological revolutions based on the criteria considered dominant in the technological development.^[2]

Technological changes are reflected on the workplace system as well: on one hand, working means and objects, technology, man's working activity structure change; on the other hand, the structure, goals and the firm organization and the society as a whole change.^[3]

This leads to new requirements including:^[3,4]

- The use of preventive philosophy (before the fact) in risk management.^[4]
- Application of systemic approach.
- Human oriented principles and the design of optimum interaction between human and machine.^[5]
- Using of integrated management systems.^[6]

Various management systems have been designed to control the hazards.^[7] Each of the existing management systems can just cover one or two aspects of the organization's goals.^[8] For example ISO 9000, ISO 14000, OHSAS 18000 can only cover the quality, environment and occupational of safety and health respectively.

Nowadays, many of the organizations use integrated management systems like HSE-Ms, HSEQ-Ms, HSSE-Ms and IMS in order to indicate that their activities and vulnerable targets are a single complex.^[9]

The implementation of integrated management systems can be done for various goals.^[10] 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. In order to achieve mentioned goals regulations and rules such as the Environmental Protection Act 1990, the Health and Safety at Work Act 1974 and the Control of Substances Hazardous to Health Regulations 1988 cannot be ignored. Customers, employees, shareholders and the community (i.e. the stakeholders) are also concerned about these matters and creating an "image" that meets customer expectations can help to improve market share.

Design of system performance measuring unit is most critical stage in integration process based on Deming continued improving cycle. The output of this unit is the most important input for controlling of integrated system's activities.

The HSEE performance management process is the process by which the company manages its HSEE performance in line with its corporate and functional strategies and objectives. The objective of this process is to provide a proactive closed loop control system, where the corporate and functional strategies are deployed to all business processes, activities, tasks and personnel, and feedback is obtained through the performance measurement system to enable appropriate management decisions.^[11]

Finding of various study identified the value of using performance measurement to deploy organization objectives and to pinpoint and monitor performance improvements.^[12] Other researchers have also noted the links between performance measures and strategic plans and/or critical success factors of the business.^[13]

In summary, the need for an integrated set of performance measures, which supports rather than contradicts organization objectives, is now clearly established.^[14] In addition, papers by Bryden and Pronovost^[14,15] asserted that performance management should be viewed as a key business process, which is central to the future wellbeing and prosperity of any manufacturing enterprise.

The main objective of this paper is to introduce and develop the concept of performance management as a key business process and focus on the criticality of the performance measurement system embedded within. It presents a reference model for the HSEE performance measurement system, which is based on industry best practice.

MATERIALS AND METHODS

The study has been done during 2009-2010 in a petrochemical unit in Iran. By determining the direct and indirect units, which have involved in HSEE systems, the research started. By drawing the data flow diagram (DFD), the trend of data's cycle related with HSEE systems has been specified and corrected. For evaluating the information systems and measuring the effect of information technology, some specific questionnaires have been designed. After that, these questionnaires were distributed among corresponding personals and operational managers and have been collected after filling out.

In this research, two groups of questionnaires were designed to evaluate the situation of the petrochemical unit from point of view of the existing information systems' productivity and the amount of information technology's effect:

- The questionnaire of measuring the effect of existing software on the output of petrochemical unit
- The questionnaire of evaluating the petrochemical unit's information systems

Mentioned questionnaires were given to authorities and experts to determine its validity regarding different sources and referring to books, journals, and publications and the questionnaire's reliability was confirmed using test-retest exam (Test-Retest) ($r = 0.76$ and $r = 0.81$ respectively).

The answers of the questionnaires are classified into five grades: no, a little, to some extent, much, so much. A model was designed for gathering, evaluating and controlling the HSEE performance indicators constantly. Based on the model the appropriate indicators, which can cover all-important

parameters in the studied unit was determined. For doing these models like phase model traffic accident, multi linear events charting method, occupational accident research unit (OARU) model, intelligent speed adaption (ISA) model, The international loss control institute (ILCI) model, TRIPOD model, domino model, energy model and accident sequence model^[16] are used. At last, the selected indicators were 79 cases in health area, 13 cases in safety area, 123 cases in environment area, 19 cases in ergonomic area and 10 cases were common indicators.

Based on determined indicators, necessary data, period and the method of collecting were specified. Standards and related national and international criterions were collected to decide about gathered indicators.

In order to confront with some of the indicators, which did not settle in determined limitations, the problem solving team was organized, and the methods of identifying problems and solving them on the basis of Deming cycle was taught.

During the study, methods of observation, interviewing with corresponding personals and operational managers and evaluating the documents were used to collect the related data. For measuring of the HSEE system's performance, the following model is designed [Figure 1] and the HSSE.1.0 software is presented.

RESULTS

The evaluating of the data's cycle is one of the necessities of an integrated systems implementation.^[17] Therefore, the data flow diagram is drawn for related units to HSEE systems in the studied petrochemical unit. These units are technical inspection, safety and fire fighting, health center, shift working and productivity. After this stage the trend of data's cycle and their framework, for example related forms, were corrected. In Figure 2, the corrected data flow diagram of safety and fire fighting unit are presented:

In order to design and have an implementation of the integrated system, the information's systems' evaluating and measuring the effect of information technology on personal is a necessity.^[18] By analyzing the questionnaire of measuring the effect of existing software on the output of petrochemical unit, the following results were gained.

Based on received answers, 41% of different units' managers stated that the effect of the software on their productivity was a lot. In this case, 17 and 28 percentages mentioned that the effect was so much and average respectively. Six percentages said that the effect was a little. On point of view of software's effect in creating innovation in petrochemical unit, 23 percentages of the personals stated that it was non-effective or with little effect. Seventy-seven percentages

mentioned that its effect was average or more. Twenty-one percentages of the personals thought that the software's effect on the internal and external customers' satisfaction

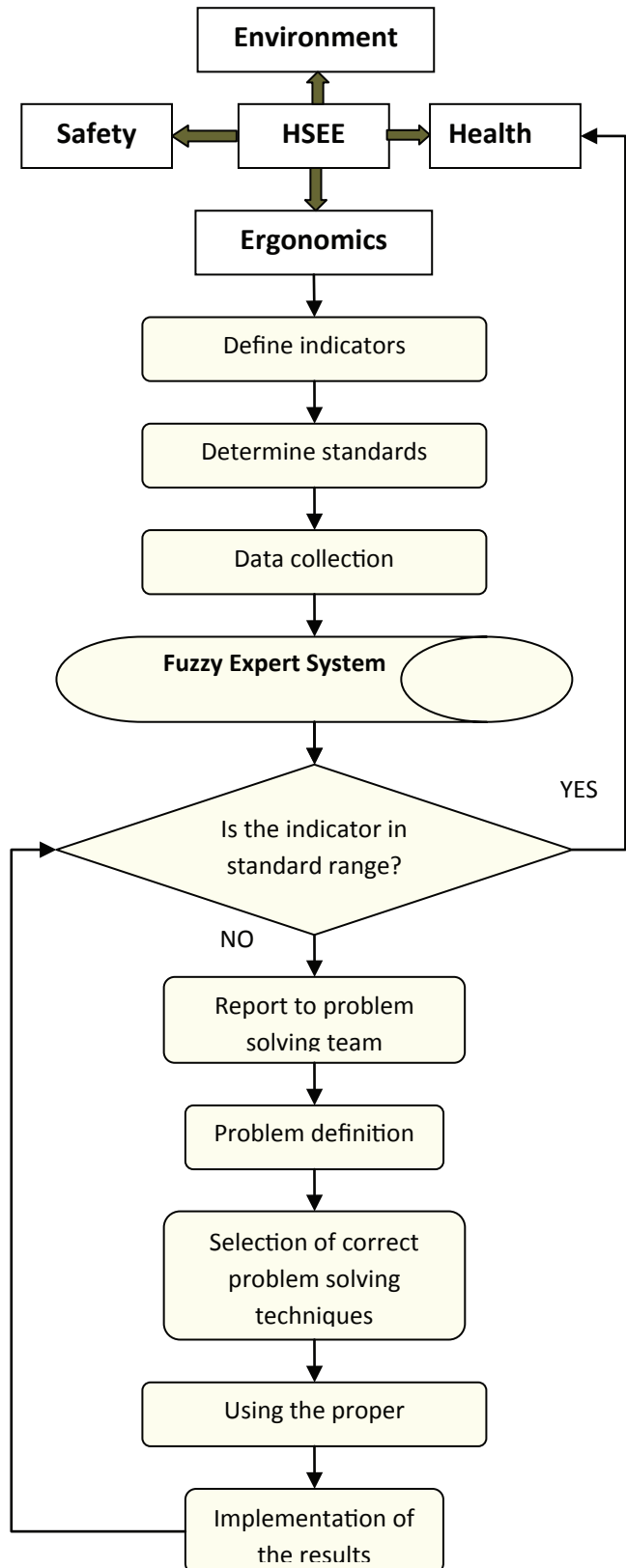


Figure 1: Performance measuring model

was a little or it was non-effective. Seventy-nine percentages mentioned that its effect was average or more. By considering the effect of software on management control, 23 percentages stated it was non-effective or with little effect and 47 percentages said that its effect was a lot or very much.

According to multidimensional models [19] the existing information systems in the petrochemical unit was also evaluated by means of standardized questionnaires from six aspects. These aspects are the quality of (information) system, the quality of information, the use of system, the user's satisfaction, the effect on personal and organizational effect [Figure 3].

The results showed that 53 percentages of personals mentioned that the quality of the information systems was low or it had no quality. Forty-seven percentages thought that its quality was average, a lot or very much. In the case of information quality, 52 percentages of personals mentioned that it had no quality or the quality was low and 48 percentages said that its quality was average, a lot or very much. Fifty-four percentages of the personals stated that the use of information systems was a little or it had no use. Forty-six percentages of them expressed that its use was average, a lot or very much. According to results 87 percentages of users had no satisfaction, less satisfaction and average satisfaction from information systems. By analyzing the questions, which were about the effect of information systems on the personals, it is defined that 79 percentages of the users mentioned that it had no effect or had a little and average effect.

By performing necessary exams it was resulted that in information technology aspect the present situation of petrochemical unit in two criteria, information systems and applied software, is weak and in designing the HSEE performance measuring systems these criteria should be considered [Table 1].

The results of the integrated HSEE system's implementation showed that the techniques, which were mostly used by the HSEE team (Problem Solving Team) during 2009-2010 were: [Table 2].

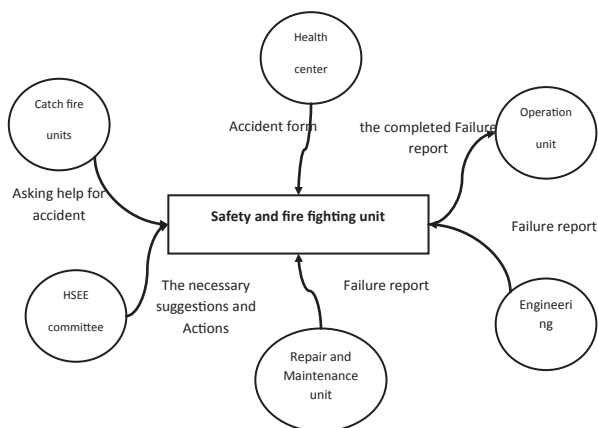


Figure 2: Data flow diagram of safety and fire-fighting unit

The most important results, which were obtained from the integrated system's implementation, were in controlling HSEE system performance indicators. Table 3 shows the impacts of utilizing system with respect to some of the most important HSEE indicators in the refinery. As shown, considerable improvement are reported with respect to these indicators.

DISCUSSION

The research's results show that if the implementation of the HSEE systems does not have any continuous monitoring or review, it would not be effective.^[17]

In providing a summary of lessons learned for the benefit of other companies undergoing a similar implementation process, it is recognized that processes differ between companies and that there is no 'right way' to implement a performance measurement system.

The result of study showed the process of development of the HSEE performance measuring system influenced by a

Table 1: The weak aspects in information area

The aspects that must be considered	Information technology area
<ul style="list-style-type: none"> The quality of the treatment's present information systems' information: the quality and rectitude of system's input data and output information, being on time and the way of system's presenting information, the advantage (the profit of available information) and the cost of information 	Information Systems
<ul style="list-style-type: none"> The effect of information systems on people: the accordance of the system's presented information with the people's needs, system's effect on making decisions, system's effect in people's productivity 	Practical software
<ul style="list-style-type: none"> The effect of software on innovation of people in performing the treatment's activities 	
<ul style="list-style-type: none"> The effect of software on the treatment's internal and external customers satisfaction 	

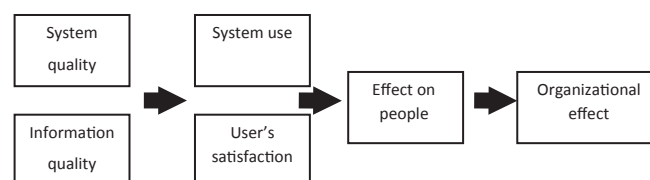


Figure 3: The multidimensional model of William H. DeLone Ephraim R. McLean

Table 2: Problem-solving techniques

Techniques	Description
(Hazard and Operability Studies) Hazop	HAZOP entails the investigation of deviations from design intent for a process by a team of individuals with expertise in different areas.
(Failure Mode and Effect Analysis) FMEA	FMEA is a bottom-up approach that looks at the failure of each element of a system or process and identifies the consequence of each failure.
(Fault Tree Analysis) FTA	A fault tree is a logical diagram, which shows the relation between system failure, i.e. a specific undesirable event in the system, and failures of the components of the system. ^[2] It is a technique based on deductive logic.
(Job Safety Analysis) JSA	A Job Safety Analysis (JSA) is a method that can be used to identify, analyze and record 1) the steps involved in performing a specific job, 2) the existing or potential safety and health hazards associated with each step, and 3) the recommended action(s)/procedure(s) that will eliminate or reduce these hazards and the risk of a workplace injury or illness.
(Quick Exposure Checklist) QEC	This technique allows for various exposure scores for the back area, the shoulder/arm area, the wrist/hand area and neck to be assessed. It uses a grid system to calculate the scores for the various body parts, based on the assessment of the analyst and of the worker.
Nordic Questionnaire	The Nordic Questionnaire is designed for the assessment of psychological, social, and organizational working conditions: 1) to provide a basis for implementing organizational development and interventions, 2) for documentation of changes in working conditions, and 3) for research into associations between work and health.
(predictive human error analysis) PHEA	The quantitative methods for prediction and analysis of human errors during work.
Anthropometrics	The systematic collection and correlation of measurements of the human body. Anthropometrics are used to describe the "user" or "target" population for a product.
Zero defects	At the heart of HSEE is a commitment to continuous improvement, the basis of which is the belief that within any situation or activity, there is always room to improve. However, here the goal is perfection or "Zero Defects," nothing less. This goal applies to every piece in the puzzle: people, processes and products. All must work together to provide the foundation for zero-defect.
Is/Is not matrix	Determining the template of similar cases' specifications by means of a classified structure
Nominal group	The Nominal Group Technique is a structured decision making process designed to involve all group members, encourage multiple ideas, insure thorough consideration of ideas, and generate an optimal group decision.
Cause and Effect Analysis	Cause-effect analysis is a well-documented diagrammatic technique designed to unearth the root cause of problems and subsequent effects. Cause-effect analysis diagram use standard grouping categories to ensure that all possible causes are considered.
Idea writing	Making partnership among people in team working
Criteria testing	Evaluating and comparing the replaced solutions by ranking them on the basis of determined gauges
Contingency Planning	Contingency planning is a systematic approach to identifying what can go wrong in a situation. Rather than hoping that everything will turn out OK or that "fate will be on your side", a planner should try to identify contingency events and be prepared with plans, strategies and approaches for avoiding, coping or even exploiting them
Safety Behavior Sampling	Determining of unsafe behaviors' portion and the type and importance of them among people

number a factors, including: the background experience of the HSEE team; communication between team members; input to the implementation Process from safety, health, environment and ergonomic management; the contract nature of the company's Business; the integrated nature of interfaces with clients; and the high level of influence exerted over relatively large numbers of subcontractors.

The findings show that, this system causes the improvement of several operational indicators. The result would be the health of internal customers, organization's environmental and hardware assets. The results of similar researches have supported these findings.^[17,18] In addition to this, the system

will increase the partnership of people in HSEE. In other words, the system has also washed out the people's need to partnership.^[19]

These results are consistent with those of Stanislav (2003) and Georgakaki (2006), who found that when health, safety and environments (HSE) performance assessment system actively supports safety programs and efforts, partnership of people in HSE are higher than when such support is not apparent.^[20,21]

In addition, these results are consistent with those of Holdsworth (2003). These results are also consistent with

Table 3: The impacts of utilizing system in the refinery

Indicators		Year	
		2009	2010
Safety Indicators	Safety culture score	73	61
	% of unsafe acts	31.5	20.4
	Near miss rate	0.44	1.4
	Accident severity rate	0.64	0.42
	Accident frequency rate	55.95	48.44
Ergonomics Indicators	Workplace Lighting		
	• Control room1	555.3	610
	• Control room2	497.8	525
	WBGT of:		
	unit 500	32.7	27.0
	unit 1000	33.0	29.1
	unit 700	31.3	31.3
	PMV _{PPD}		
	• Control room1	30	13
	• Control room2	41	17
Environmental Indicators	Musculoskeletal disorders rate	43	37.2
	Emitted NOx gases from unit 900 stake (PPM)	121	76
	Emitted SOx gases from unit 500 stake (PPM)	230	45
	Emitted CO from unit 600 stake (PPM)	345	222
	Emitted dust from unit 900 stake (ml/M ³)	60	19
	Sound level – Night (dB)	50	42
	Sound level – Day (dB)	71	55
Health Indicators	Pre employment medical examinations to number of employed people in a given period (%)	93.7	100
	Periodic examinations from worker with harmful works to total number of workers (%)	76	97.3
	Periodic examinations from workers whose work has changed	0	67.8
	Periodic examinations from workers who were away from their work environment for more than one month	0	71.7
	Color (Pt-co) – Water	14	6
	PH- Water	11.3	8.7
General Indicators	Darkness (JTU) – Water	17	6.4
	Suitability of HSEE committee discussions	64.8	87.4
	Execution of HSEE committee discussions	55.9	91.3
	Tasks clarification of HSEE committee members	37.3	100
	Execution of tutorial program according to tutorial calendar	46.9	87.2

other research studies that sought to identify factors at companies with successful safety results (Ho, 2008 and Lozano, Valles, 2007). In these studies, all found that companies with HSE performance assessment system had more programs that promoted employee involvement in safety.^[22-24]

To make a summary of the research and development work presented in this paper we may mention the following points.

Generally, the performance management process is seen as a closed loop control system, which deploys policy and strategy, and obtains feedback from various levels in order to manage the performance of the business. It is also believed that the performance measurement system is the information system, which is at the heart of the performance management process, and therefore, of critical importance to the effective and efficient functioning of the performance management system.

Results from the research have identified integrity and deployment as two critical elements with respect to the content and structure of the performance measurement system.

It is also worth mentioning that the reference model developed for integrated performance measurement systems provides a framework against which performance measurement system can be designed and audited.

Taking all this into account it should not be overlooked that there are obstacles which company could encounter during an HSEE performance measuring system adoption process that could delay the system implementation and certification.

Roles and responsibilities might not be clearly defined within the company and lack of proper communication with and training for the employees might result in the system implementation and certification failure. Moreover, the shop-floor workers could be 'uneducated, unskilled' and thus lack the capability to identify and correct the potential risks and hazards associated with their work. Finally, lack of correct, timely resource availability such as legal expertise, dollars, especially by small and medium enterprises is also considered to hinder the system.

The reported findings in this paper emphasize the need to conduct further research in this area, in particular, the

continuous monitoring of mentioned system in future years and performing necessary corrections.

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