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Optimization of HSE in maintenance activities by integration of continuous improvement cycle and fuzzy multivariate approach: A gas refinery

A. Azadeh*, Z. Gaeini, B. Moradi

School of Industrial Engineering and Centre of Excellence for Intelligent-Based Experimental Mechanics, College of Engineering, University of Tehran, Iran

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ABSTRACT

Gas refineries have been continuously focusing on Health, Safety and Environment programs to improve maintenance activities. Several researches have studied on this area with different analysis methods. This study presents an integrated approach for optimization of factors contributing to the implementation of Health, Safety and Environment (HSE) in maintenance activities. HSE managers in each sector answered standard questionnaire whit respect to HES. The methodology is based on fuzzy data envelopment analysis (FDEA) and Deming's continuous improvement cycle. Also, this method is used to rank the relevant performance efficiencies in certain and uncertain conditions of each HSE sectors whit considering HSE in maintenance activities. It corresponds and integrates its registered HSE-MS with OHSAS 18001:2007 and ISO 14001:2004 to evaluate multiple inputs and outputs of over 36 subsidiary HSE divisions with parallel mission and objectives simultaneously. Also, it determines efficient target indices and could assure continuous improvement in the organization. This is the first study that introduces an integrated approach to improve HSE management programs in a gas refinery by a robust and continuous improvement approach.

Motivation and significance

Gas refineries have significant role to the growth of national economies. Also, the development of the sector could lead to a considerable reduction of costs. Given the hazardous nature of their extended operations, the management system can play an important role to reduce the risks of sectors. This study for the first time presents analysis and optimization of human factors by use of DEA (Data Envelopment Analysis) and fuzzy DEA to overcome such issues as human error and corrupted data in gas refineries.

1. Introduction

Maintenance process is a sequence of physical actions and information activities that required to prevent a failure or to repair equipment to a satisfactory operating condition. Maintenance work is also an intensive knowledge and a complex activity, where the personnel come in direct contact with the equipment. It is mostly a manual activity which is yet to be automated. Over the years, although the reliability of equipment has improved, yet humans continue to be unpredictable. Human errors in maintenance result in the failure of performing a specified task or tasks, carrying out an incorrect repair task or performing a forbidden action during routine testing, checking, servicing or repair (Kumar and Gandi, 2011). This can happen because of a variety of reasons, such as lack of knowledge, skill and experience, workplace conditions, and lack of communication.

Based on Deming's Continuous Improvement Cycle; health, safety, environment, ergonomics, and macro ergonomic management systems would significantly minimize the risks and also could increase performances through continuous learning from past experiences (Azadeh et al., 2012a,b). Also, it encourages employees to apply these facts in their life style. Continuous improvement leads to energy consumption and minimizing the waste. Therefore this system should consider the relation between machine and human to minimize the weariness for operators and obtain the most efficiency in each sector (Azadeh et al., 2008; Changchit and Holsapple, 2001).

This study takes proactive and reactive stance and submits a proposed method for performance assessment and optimization of HSEE management systems to further enrich this body of research. It demonstrates how Data Envelopment Analysis (DEA) with the

* Corresponding author.
E-mail address: aazadeh@ut.ac.ir (B. Moradi).

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help of fuzzy enables a conventional gas refinery with uncertain data sets to simultaneously analyze multiple output/input indicators to: a) precisely determine technical efficiencies, b) completely rank the divisional efficiencies, and c) diligently set efficient target indices for its HSE management systems (Table 1).

2. Literature review

In this study an integrated fuzzy approach and the continuous improvement cycle is applied. Within the HSE literature, analyzing of maintenance system management by using of optimizing tools is applied in few studies. Analyze and improve of environmental management system are mainly important in HSE point of view.

Study about management systems in context of HSE is introduced by many researchers. In this paper, an optimization and improvement tool is applied to analyze HSE management system in maintenance activities. Analyzing HSE management system is applied by some researchers. Bernardo et al. (2009) analyzed the extent to which environmental management systems are really integrated with the quality and other standardized management systems implemented in organizations. Zutschi and Sohal (2003) highlighted the potential tangible and non-quantifiable benefits from integration. This is also applicable to management systems that register to health, safety, and environmental standards (Basso et al., 2004). Santos-Reyes and Beard (2009) have been developed a Systemic Safety Management System (SSMS) model. The SSMS aims to maintain risk within an acceptable range in the operations of any organizations in a coherent way. This paper presents an application of the SSMS model to an oil and gas organization. In addition to studies on HSE management models, Fernández-Muñiz et al. (2007) evaluated the most important works on safety management, and subsequently calculating its reliability and validity. Cox and Cheyne (2000) and Fitzgerald (2005) took proactive stance to assess the safety culture performance through different tools – namely, safety climate assessment toolkit, and behavioral and safety auditing system, respectively.

In order to apply HSE concepts in management systems, to investigate the status of implementing occupational health and safety management systems (OHSMSs), and to explore important performance indicators for OHSMSs' performance appraisal in the printed circuit board (PCB) industry in Taiwan, Chen et al. (2009) administered a survey to eleven PCB manufacturers, all of which have been certified as compliant to the guidelines on OHSMS of the Occupational Health and Safety Assessment Series (OHSAS) 18001, and twenty six OHSAS specialists from the academe. Chang et al. (2009) developed a model to evaluate the performance of process safety management systems of paint manufacturing facilities. The model was constructed based on a three level multi-attribute value model (MAVT) approach. Einarsson and Brynjarsson (2008) suggested an approach for a human factor program as a learning experience through case studies from incidents and accidents in Iceland and Netherlands.

HSE at the operational level will strive to eliminate or decrease injuries, adverse health influences and hurt to the environment. Various studies have shown positive influences of applying ergonomic rules to the workplace including machine, job, and environmental design (Shikdar and Sawaqed, 2004). Studies in ergonomics have produced data and instructions for industrial applications. However, there is still a low level of acceptance and few applications in industry. The main concern of work system design in context of ergonomics is improvement of machines and tools. Lack of utilization of the ergonomic rules could bring inefficiency to the workplace. Besides; an ergonomically deficient workplace can cause physical and emotional stress, low productivity, and poor quality of work conditions (Burri and Helander, 1991).

All these studies analyzed and evaluated HSE management system in organization. But, they did not present an improvement tool for the system. HSE systems are changing frequently and need to be improved according to evolving situation. Also, all the cases are applied with certain data set and uncertainty is not considered in measurements. Therefore, in this paper a continuous improvement approach is presented to consider this aspect of HSE systems in maintenance activities.

There have been many efficiency frontier analysis methods reported in the literature. But, the assumptions made for each of these methods are restrictive. Conflicting conclusions of efficiency are often resulted by using the different methods due to the unsuitability of the assumptions. The non-parametric approach makes no assumption about the functional form of the frontier. Instead, it specifies certain assumptions about the underlying technology that in combination with the data set allow the construction of the production set. For instance, the DEA frontier is very sensitive to the presence of the outliers and statistical noise which indicates that the frontier derived from DEA analysis may be warped if the data are contaminated by statistical noise (Bauer, 1990).

The applied method for optimization in this study is Data Envelopment Analysis (DEA) and also Fuzzy DEA (FDEA) to calculate efficiencies. Data envelopment analysis (DEA) is a good solution to evaluate the performance of systems in a multi input-multi output environment. DEA is one popular optimization method used for measuring the relative efficiency of DMUs. Thus, in this part some studies that used DEA method are reviewed. There are some researches that applied DEA tool to measure efficiencies in different areas such as police precincts and banks (Wu et al., 2010; Mercan et al., 2003). Data envelopment analysis is also a method for estimating efficiencies or inefficiencies of Decision Making Units (DMUs) by means of weighted output to input ratios, being the weights optimal virtual prices of such ex-post activities for all units (Rödder and Reucher, 2011; Cook and Zhu, 2005).

Because of uncertainty in data and information, fuzzy approach is selected for evaluating performance. In the real world input/output data are imprecise and fuzzy linear programming helps to analyze performances (Lertworasirikul et al., 2003). The DEA models with fuzzy data can represent real-world problems better than the conventional DEA models. There are many researches on ranking fuzzy data sets. Therefore, to overcome the uncertainty problem using FDEA is a good approach in many studies (Kao and Liu, 2000; Lertworasirikul et al., 2003). This method also used in different areas in manufacturing environments. Wang et al. (2009) applied two fuzzy DEA model to optimize and rank efficiencies of eight manufacturing enterprise in China. Also, assessment and evaluation of bank branches from different regions is done by Wu et al. (2006) with using of FDEA. Moreover, results are compared with the results from traditional DEA in this study. Wen and Li (2009) presented a hybrid algorithm combined with fuzzy simulation and genetic algorithm.

Furthermore, DEA and FDEA approaches are used in some studies in HSE and maintenance area. Azadeh et al. (2014) evaluated maintenance and HSE systems of a gas transmission unit by

Table 1
Table of acronyms in this study.

1	Health, safety, environment	HSE
2	Decision making unit	DMU
3	Date envelopment analysis	DEA
4	Fuzzy date envelopment analysis	FDEA
5	Plan, do, check, act	PDCA