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Original Article

An Efficient Taguchi Approach for the Performance Optimization of Health, Safety, Environment and Ergonomics in Generation Companies

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ABSTRACT

Background: A unique framework for performance optimization of generation companies (GENCOs) based on health, safety, environment, and ergonomics (HSEE) indicators is presented.
Methods: To rank this sector of industry, the combination of data envelopment analysis (DEA), principal component analysis (PCA), and Taguchi are used for all branches of GENCOs. These methods are applied in an integrated manner to measure the performance of GENCO. The preferred model between DEA, PCA, and Taguchi is selected based on sensitivity analysis and maximum correlation between rankings. To achieve the stated objectives, noise is introduced into input data.
Results: The results show that Taguchi outperforms other methods. Moreover, a comprehensive experiment is carried out to identify the most influential factor for ranking GENCOs.
Conclusion: The approach developed in this study could be used for continuous assessment and improvement of GENCO's performance in supplying energy with respect to HSEE factors. The results of such studies would help managers to have better understanding of weak and strong points in terms of HSEE factors.

1. Introduction

Health, safety, and environment (HSE) 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. This can enhance worker productivity, provide improved worker safety (physical and mental), and job satisfaction [1]. Several studies have shown positive effects of applying ergonomics principles to the workplace including machine, job, and environmental designs [2–9].

There are many factors in the ergonomics design of a workplace in both micro and macro parts, and therefore, it seems inevitable to consider a model that includes all related factors. Microergonomics consider those factors of machine design and work posture that affect the user interface and working conditions related to the job or task design. In a macroergonomics study, ergonomics factors are considered in parallel to organizational and managerial aspects of working conditions in the context of a total system design. Moreover, it attempts to create equilibrium between organization, operators, and machines. It focuses on total "people-technology" systems and is concerned with the impact of technological systems on organizational, managerial, and personnel subsystems [10,11]. Studies in ergonomics have produced data and instructions for industrial applications [12–14]. Eklund [15] presented the relationships between ergonomics and several factors such as work conditions, product design, ISO 9000, continuous improvements, and total quality management. Azadeh et al [11] described an integrated macroergonomics model for operation and maintenance of power plants. By considering HSE, an organization manages its operations in a manner that places safety and health first. Champoux and Brun [16] gave an overview of the most characteristic occupational health and safety representations and practices in small firms. Chang and Liang [17] developed a model to evaluate the performance of process-safety-management systems of paint-manufacturing facilities based on a three-level multiattribute

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approach. Singh et al [18] considered the state of the art of understanding the hazards and risks to human health and the environment associated with the use of synthetic chemicals as a basis for developing a risk-assessment procedure for the mining industry. Duijm et al [19] showed that HSE management would benefit greatly from existing management systems and also from the further development of meaningful safety-performance indicators that identify the conditions prior to accidents and incidents. Hassim and Hurme [20] presented an inherent occupational health index for assessing the health risks of various processes. The method considers the hazard from the chemicals and also the potential for the exposure of workers to the chemicals. The certification and implementation of occupational health and safety-management system had become a priority for many organizations. Boughaba et al [21] elucidated the relationship between safety culture maturity and safety performance of a particular company.

HSE and ergonomics (HSEE) have been considered from different points of view [22–24]. A close relationship exists between HSEE factors. Inappropriate design between human and machine could lead to decreased safety. Inappropriate design of system leads to management error. Management error and work-environment-injurious factors could cause human error and safety issues, which consequently would result in environmental risks. It is believed that ergonomics deficiencies in industries are the root cause of workplace health hazards, low levels of safety, and reduced workers' productivity [16].

This study has identified major HSEE indicators, which affect the performance in generation companies (GENCOs). According to the literature, it is realized that HSEE systems require a continual and systematic effort to achieve sustainable success. This paper presents a framework for a comprehensive performance analysis of GENCOs in terms of HSEE factors, which we refer to from this point on to as HSEE.

2. Materials and methods

An integrated Taguchi–data envelopment analysis–principal component analysis (Taguchi–DEA–PCA) approach is proposed for ranking the GENCO's performance based on HSEE indicators. For ranking this sector of industry, the combination of DEA, PCA, and Taguchi is efficiently used for all branches of the GENCO. All of the useful and influential points of these methods are used to measure the GENCO's performance. First, standard indicators are identified and required data are gathered. These indicators are related to HSEE. The structure of the proposed Taguchi–DEA–PCA approach is shown in Fig. 1.

According to the proposed approach, first the standard inputs are determined, collected, and standardized by considering HSEE factors for all branches in GENCO. Then different scenarios are designed by corrupting 5–10% of data to model the complex and vague environment from which data are collected. The DEA, PCA, and Taguchi models are applied for ranking these scenarios. Finally, correlations between rankings for the designed scenarios are calculated and the preferred model is selected based on the maximum correlation. This shows the most consistent model for ranking scenarios in complex, vague, and uncertain environments. In the following sections, the DEA, PCA, and Taguchi models are described.

2.1. Data envelopment analysis

Consistent with DEA terminology, the term "decision-making unit" (DMU) refers to the individuals in the evaluation group. The DEA generates a surface called the "frontier" that follows the peak performers and envelops the remainder [25]. Fig. 2 illustrates the concepts of the empirical and theoretical production frontiers in a two-dimensional surface to generalize the case of a multidimensional surface. The theoretical frontier represents the absolute

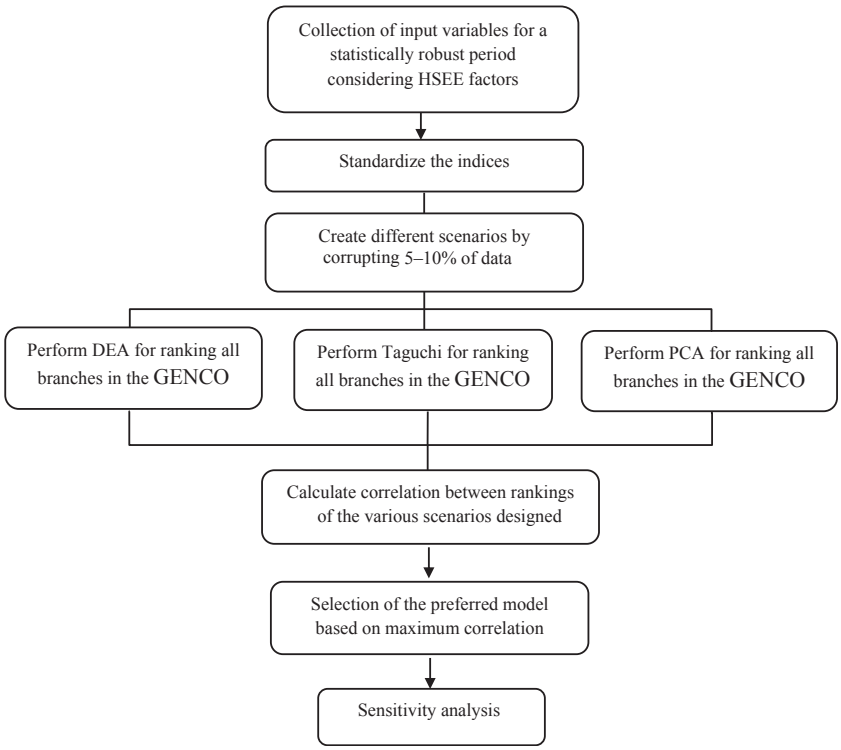

Fig. 1. Structure of the proposed approach. DEA, data envelopment analysis; GENCO, generation companies; HSEE, health, safety, environment and ergonomics; PCA, principal component analysis.