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A flexible intelligent algorithm for identification of optimum mix of demographic variables for integrated HSEE-ISO systems: The case of a gas transmission refinery

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ABSTRACT

This study proposes a flexible intelligent algorithm for assessment and optimization of demographic features on integrated health, safety, and environment and ergonomics (HSEE)-ISO systems among operators of a gas transmission refinery. To achieve the objectives of this study, standard questionnaires with respect to HSEE and ISO standards are completed by 80 operators. Demographic features include age, education, gender, weight, stature, marital status, and work type. The average results for each category of HSEE are used as inputs and effectiveness of ISO systems (ISO 18000, ISO 14000, and ISO 9000) are used as output for the intelligent algorithm. Artificial Neural Networks (ANN) and Adaptive Neuro Fuzzy Inference System (ANFIS) in addition to conventional regression are used in this paper. Result shows the applicability and superiority of the flexible intelligent algorithm over conventional methods through mean absolute percentage error (MAPE). Computational results show that the proposed ANN performs better than ANFIS and conventional regressions based on its relative error. Finally, the optimum mix of demographic variables from viewpoint of HSEE and ISO are identified. This is the first study that proposes a flexible intelligent algorithm for assessment of optimum mix of demographic features for HSEE and ISO systems in a complex system such as a gas transmission refinery.

1. Introduction

1.1. Motivation and significance

Nowadays, managers of several industries have a practical interest to HSE, ISO systems and the cases influence on efficiency of their industry. Conventional approaches such as regression are usually used for identification of optimum mix of demographic variables. Moreover, most demographic variables of are fuzzy and non-crisp nature. Therefore, this study uses ANN and ANFIS in addition to conventional regression approaches for such objectives. In reality, demographic features can effectively enhance integrated HSEE-ISO systems. The proposed algorithm can aid managers to employ an optimum mix of operators with respect to demographic features. This study for the first time presents a flexible intelligent algorithm for identification of optimum mix of demographic features for integrated HSEE-ISO systems in a gas transmission refinery.

1.2. Demographic variables

Basha and Maiti (2013) examine the associations amongst job-risk perception, work injuries and demographic variables like age, experience, designation and location of work in an integrated steel plant in India. The job-risk perception was measured using 'job safety' questionnaire and actual safety performance was measured using self reported injury experiences. DeJoy, Schaffer, Wilson, Vandenberg, and Butts (2004) after controlling for demographic variables, three factors: environmental conditions, safety-related policies and programs, and general organizational climate, accounted for 55% of the variance in perceived safety climate.

Rönnlund and Nilsson (2006) demonstrate the need to control for cohort and retest effects in cross-sectional and longitudinal studies, and reveal interesting relations between Block Design Test (BDT) performance and demographic variables. Goldberg, Sweeney, Merenda, & Hughes (1998) using a large ($N = 3629$) sample of

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individuals selected to be representative of U.S. working adults in the year 2000, they provide the correlations between each of four demographic variables (gender, age, ethnic/racial status, and educational level) and each of the dimensions from two quite different five-variable representations of personality traits.

Reynolds and Gutkin (1981) investigated the performance of 285 matched pairs of Black and White children from the standardization sample on the 12 subtests and 3 IQ scales of the Wechsler Intelligence Scale for Children—Revised (WISC-R). The children were matched on four demographic variables found in a previous study to be significantly related to WISC-R performance: sex, socioeconomic status as determined by the occupation of the head of household, region of residence in the U.S. and urban vs. rural residence.

1.3. Process safety

Chemical accidents during process plant shutdowns may have severe consequences. In spite of this, the safety management systems in place in many companies still mainly cover the normal operations and little explicitly address the maintenance shutdown and plant start-up phases. A Finnish research project found that the level of safety during shutdowns is more closely related to the skills of key individuals at the plants and less due to the systematic safety management system of the companies (Malmén, Nissilä, Virolainen, & Repola 2010).

Sanders (2004) reviews a few public perceptions of safety in chemical plants and refineries, and will compare these plant work place risks to some of the more traditional occupations.

The handling of safety, health, and environmental (SHE) issues in small process plants has been addressed in the European project named Small Plants—Assistance with Safety and Environment (SPASE). Harms-Ringdahl, Jansson, and Malmén (2000), results from a questionnaire to small process plants in five countries are presented.

Beriha, Patnaik, Mahapatra, and Padhee (2012) present an artificial intelligence approach for prediction of different types of accidents (fatal to minor) in an uncertain environment. Likelihood of occurrence of accidents in the work place is a random phenomenon but judicious investment in various attributes such as expenses in health care, safety training, up-gradation of tools and machinery, and expenses on safety equipment and tools may lead to reduction in accident rate.

Safety assessment of thermal power plants (TPPs) is one of the important means to guarantee the safety of production in thermal power production enterprises. Due to various technical limitations, existing assessment approaches, such as analytic hierarchy process (AHP), Monte Carlo methods, artificial neural network (ANN), etc., are unable to meet the requirements of the complex security assessment of TPPs (Liang et al., 2012).

Indices are extensively used for ranking various units of a chemical process industry on the basis of the hazards they pose of accidental fires, explosions and/or toxic release. This type of ranking enables the professionals to identify the more hazardous units from the less hazardous ones so that greater attention can be paid to the former (Khan, Husain, & Abbasi, 2001).

The design of layout plans requires adequate assessment tools for the quantification of safety performance. The general focus of the present work is to introduce an inherent safety perspective at different points of the layout design process. In particular, index approaches for safety assessment and decision-making in the early stages of layout design are developed and discussed in this two-part contribution (Tugnoli, Khan, Amyotte, & Cozzani, 2008).

1.4. ISO systems

The ISO 9000 family of standards relates to quality management systems and is designed to help organizations ensure they meet the needs of customers and other stakeholders. ISO 9000 deals with the fundamentals of quality management systems (Curkovic, Sroufe, & Melnyk, 2005; Koc, 2007; Lo, Yeung, & Cheng, 2009; Sharma, 2005; Singh, Power, & Chuong, 2011; Turk, 2006).

The ISO 14000 environmental management standards exist to help organizations (a) minimize how their operations (processes etc.) negatively affect the environment (i.e. cause adverse changes to air, water, or land); (b) comply with applicable laws, regulations, and other environmentally oriented requirements, and (c) continually improve in the above. ISO 14000 is similar to ISO 9000 quality management in that both pertain to the process of how a product is produced, rather than to the product itself. As with ISO 9000, certification is performed by third-party organizations rather than being awarded by ISO directly (Castka & Balzarova, 2008; Chen, 2005; Miles, Munilla, & McClurg, 1999; Mohamed, 2001; Quazi, Khoo, Tan, & Wong, 2001; Sherrington, Sperring, & Williamson, 2005).

The ISO 18000 certification (or OHSAS 18001) covers Occupational Health and Safety Management Systems in order to enable businesses to be confident they are doing all they can to protect their employees. It also allows the business to ensure they are operating according to their stated health and safety policies. As with all ISO standards, ISO 18000 has a focus on continuous improvement which is particularly important for health and safety. ISO 18000 is designed to compliment other ISO standards and is often put in place alongside ISO 9000 and 14000 to save going through 3 rounds of preparation and auditing. ISO 18000 Covers:

- Preparing plans for hazard identification and risk assessment/control
- Occupational Health and Safety Management programs
- Staff Training and awareness of duties
- Operational control
- Emergency plans
- Continuous monitoring and improvement.

2. Methodology

A flexible intelligent algorithm is proposed for assessment and optimization of demographic features to integrated HSEE-ISO systems with fuzzy and uncertain variables. To achieve the purpose of this study a standardized questionnaire is distributed among employees of a gas transmission refinery. It consists of the following thirteen steps. Fig. 1, shows the flexible intelligent algorithm for assessment and optimization of demographic features on integrated HSEE-ISO systems.

Step 1. Determine reliability of the questionnaire. In this step Cronbach's Alpha is used for all questions of the questionnaire to check the reliability of the questionnaire.
Step 2. Determine the validity of the questionnaire. Factor analysis has been applied for determining the validity of questionnaire.
Step 3. Demographic features include age, education, gender, weight, stature, marital status, and work type.
Step 4. All mix of demographic features is specified.
Step 5. Assume that there are n operators to be evaluated. For each combination of demographic features, each operator is placed in one of mixes on respective combination.