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Modeling and optimizing efficiency gap between managers and operators in integrated resilient systems: The case of a petrochemical plant

*A. Azadeh**, *V. Salehi*

School of Industrial and Systems Engineering, College of Engineering, University of Tehran, Iran

ABSTRACT

The reliability issue in complex industrial systems such as oil, gas, petrochemical companies, nuclear and aviation industries has been of great importance. Resilience engineering (RE) is a new attitude toward the improvement of safety and reliability in the stated systems. One of the challenges a resilient system might face is the gap between work as imagined by managers and work as actually done by operators. This study will introduce a new framework named integrated resilience engineering (IRE) as a result of developing the concept of RE. The data used in this research have been obtained by means of questionnaire from a petrochemical company. Thereafter, the efficiency of operators and managers are calculated in RE and IRE frameworks through data envelopment analysis (DEA) approach. Then, the gaps between managers and operators are analyzed in two frameworks. The results are indicative of a significant growth in the number of efficient operators and managers in IRE framework compared to RE framework. Besides, the efficiency mean of managers and operators in IRE framework has experienced the growth of 1.8% and 5% compared to RE framework, respectively. The efficiency gap between managers and operators in IRE framework has also enjoyed the improvement of 88% compared to RE framework. Generally, it can be said that the suggested items of this research has led to the betterment of managers and operators' efficiency and of the efficiency gap between them. Therefore, these items can improve the resilience and safety of complex systems. The results of Spearman test show that there is a strong direct correlation between the DEA results in two frameworks. This is the first study that examines the efficiency gap between operators and managers based on the RE principles and by means of DEA approach.

Keywords: Integrated resilience engineering (IRE); Petrochemical plants; Data envelopment analysis (DEA); Efficiency gap; Managers; Operators

Motivation and significance

Resilience engineering is a new concept that can increase the reliability and safety level in high risk environments such as petrochemical plants. One of the priorities of a resilience-based system is responding to disruptions and challenges efficiently. Increasing efficiency gap between operators and managers decreases the speed of responding to disturbances and the resilience of the system is reduced as a result. Review of literature shows that the majority of studies undertaken in RE field have been qualitative. Hereby, this study introduces a framework to examine the efficiency gap between managers and operators quantitatively. The major motif of this study is twofold. It introduces a modeling approach for decreasing the efficiency gap between managers and operators and second it introduces the know how to improve the resilience level in complex systems such as petrochemical plants.

* *Corresponding author*. Tel.: +98 2188021067; fax: +98 2182084194.
E-mail address: aazadeh@ut.ac.ir (A. Azadeh).
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1. Introduction

Safety can be viewed as a control problem and safety must be managed by a control structure embedded in socio-technical and complex systems. From this perspective, adverse emergent properties in complex systems – hazardous situations or accidents – have higher possibilities to occur when flaws in the control mechanisms (technical, human, organizational) enable the emergence of unforeseen outcomes that generate negative consequences (Rasmussen and Svedung, 2000). The socio-technical and complex systems are so complicated that cannot be analyzed by traditional risk analysis dividing system and by identifying unwanted chains of events (Hollnagel, 2007). Resilience engineering (RE) has become an important field for safety management in socio-technical and complex systems (Steen and Aven, 2011).

In a world fraught with finite resources, irreducible ambiguity, and multiple conflicting goals, safety is created via proactive resilient processes rather than via reactive obstacles and barriers (Woods and Hollnagel, 2006). Furthermore an actual challenge for system safety is to identify that complex systems are dynamic and that a status of dynamic stability sometimes may change into a status of dynamic instability (Adamski and Westrum, 2003). RE is a new paradigm for safety management that focuses on the development of tools to ensure that the system keeps (or recovers to) a safe stable state (Wreathall, 2006). Also, RE is the capability of systems and organizations to anticipate and adapt to the potential for surprise and failure (Woods and Hollnagel, 2006). From the RE point of view, a resilient system is one that utilizes inherent human abilities in tune with engineered safeguards and organizational features. As a result, it will maximize the extent of a controlled manner both in expected and in unexpected conditions (Fujita, 2006).

Safety management system of a resilient organization should provide means to overcome expected and unexpected situations, allowing it to monitor, understand, reflect and learn from these strategies, perceive emergent safety threats, and feed these back to the relevant actors. Failing to do that brings the organization into a reactive mode (Woods, 2006). RE also is a safety approach based on the management of disturbances before, during, and after their occurrence (Hollnagel et al., 2006). The goal of RE is not to avoid the occurrence of perturbations but to manage them (Tazi and Amalberti, 2006). In addition, RE focuses on action to compensate for poor behavior, poor design, poor systems, and poor conditions (Furniss et al., 2011).

Several studies have been conducted in the field of RE whose purpose was often safety improvement such as helicopter transportation (Mata et al., 2006); oil distribution plant (Abech et al., 2006); refining plant (Tazi and Amalberti, 2006); aviation (Dekker et al., 2008); health and safety management systems (Costella et al., 2009); helicopter transportation (Gomes et al., 2009); high-risk process environments (Huber et al., 2009); oil and gas exploration (Storseth et al., 2009); electricity distributor (Saurin and Carim Junior, 2011); aviation (Zimmermann et al., 2011); air taxi carrier (Saurin and Carim Junior, 2012); chemical plant (Shirali et al., 2012); industrial processes (Dinh et al., 2012); petrochemical plant (Azadeh et al., 2013).

Performance evaluation of human resources in most systems is an issue of paramount importance for managers, researchers, and decision-makers. There are different approaches for performance evaluation of personnel in any system. DEA is one of the most well-known methods. It has a lot of usages in engineering case studies such as the following examples, data mining (Kusiak and Tseng, 2000), optimization of power distribution unit (Azadeh et al., 2009), location optimization of wind plants (Azadeh et al., 2011) and performance assessment of integrated resilience engineering (Azadeh et al., 2013).

A new framework, namely IRE, will be introduced in this study. It contains RE principles (proposed by Hollnagel et al.) and four items that will be proposed in this study (Fig. 2). Therefore, RE framework will be a subcategory of IRE.

The gap and distance between the work as imagined by managers and the work as actually done by operators and staff is one marker of system resilience. The long distance or large gap indicates that management system might not operate efficiently in the face of challenges and disturbances in real operations. Generally, the consequence of large gap will be the brittleness in the face of threats and disturbances (Wreathall, 2006). It is essential for RE to monitor and learn from the gap between work as imagined and work as practiced. Anything that ignores the mentioned gap will make it impossible for the system to adjust its understanding or model of itself and thus damage processes of learning and improvement (Hollnagel and Woods, 2006). When this gap decreases, a balance will be established between safety and production. Therefore, there will be a higher level of resilience and an increase in the system capability in the face of challenges and disturbances. As a result, safety improves in the whole of system (Dekker, 2006).

Analyses of the gap between the work as imagined and the work as actually done revealed how people in their various roles throughout systems always struggled to anticipate paths toward failure, to create and sustain failure-sensitive strategies, and to maintain margins in the face of pressures to increase efficiency (Hollnagel et al., 2006). In addition, safety progress depends on providing operators and managers with information about changing vulnerabilities and the ability to develop new means for meeting them (Woods and Hollnagel, 2006).

A key factor in all examples of RE is to have a realistic understanding of work as actually performed, and then engineering all the tools and processes to use the beneficial features of that work, and to eliminate systems and processes that get in the manner of work being performed safely and effectively. This similar need applies at the organizational levels as well as the personnel's level. How does the organization actually accomplish its work and how does that impact safety? Hence there is a need for measures of organizational behavior and human performance (Wreathall, 2006). It is noted that in this study, Hollnagel's work has been extended. It has been done so for improvement of safety situations in high-risk systems. In addition, Hollnagel's work and other similar works which have been done in RE field are qualitative. In the real word, managers and engineers need tangible data for decision making process. In this study, the behavior of a real system is examined by considering of RE concept. Also, the effect of suggested items is discussed in a quantitative form by means of DEA approach.

This study is mainly aimed at giving a suggestion for improving of safety situation through decreasing the efficiency gap between managers and operators. After data collection, the efficiency of managers and operators will be calculated in RE and IRE frameworks by means of DEA approach. Then, efficiency gap will be calculated in both frameworks. At