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A fuzzy analytic network process (ANP) model to identify faulty behavior risk (FBR) in work system

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Abstract

Work system safety is a function of many factors, besides it is dynamic and complex. There may be relations and dependencies among the safety factors. Therefore, work system safety should be analyzed in a holistic manner. In this study, the faulty behavior risk (FBR) which is significant in work system safety is tried to be determined through analytical network process (ANP) which is an extension of analytical hierarchy process and allows analysis of complex systems. Besides, there are many difficulties and limitations in measuring the faulty behavior factors. For this reason, the weights of factors and sub-factors necessary to calculate the FBR are determined by using fuzzy ANP and by this way it was possible to make better decisions in this process.

Keywords: Safety management; Work system; Multi-criteria decision analysis; Fuzzy AHP, ANP

1. Introduction

In the work system, fault is usually defined as the deviation from the reasonable, designed and expected behavior standard (Ozgüven, 2003). Faulty behaviors are the behaviors which either decrease or have the potential to decrease the safety and performance of the work system. Unwanted or inappropriate behaviors are also considered faulty behaviors (Sabancı, 1999). Work systems are usually classified into three groups, namely manual, mechanical and automated systems, according to the ergonomics aspects (McCormick, 1982). No matter how complex and comprehensive the work systems are, the human and machinery factors determine the performance and running of the work systems (Kurt, 1993). Synchronous and harmonious running of the human and machine factors in the work system depends on the safety performance of the work system. The safety performance is possible if only there is an effective safety management. In this context, measuring the probable risks of factors that cause faulty behaviors in the work systems is important for the safety performance.

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In the literature of the safety management, there are many methods proposed or developed in order to measure the safety performance. The main methods are the accident statistics, the accident control chart, and the attitude scales (Brauer, 1994). However, most of these methods are passive or subjective methods. For example, the accident statistics only shows the performance of the safety management in the past, whereas the accident control chart demonstrates the current state of the safety management. The attitude scale includes a measurement which is both subjective and qualitative. For these reasons, none of these methods can evaluate the current state of the safety management quantitatively and estimate the occurrence probability of unwanted events (Chen and Yang, 2004). However, in his study, Qien (2001a,b) has taken a broad step towards the development of a risk indicator that capable of providing a signal or warning. His methodology includes an eight-step procedure including identification of risk influencing factors, assessment of potential change in risk influencing factors, assessment of effect of change in risk, and selection of risk indicators (Chen and Yang, 2004).

In another study, which was carried out to determine the current safety performance indicator of the work system, it is proposed to link the safety climate with the actual characteristics of the workplace obtained from worker questionnaires (Dedobbeleer and Beland, 1991). Williamson et al. (1997) linked the safety climate with the perception of workers about their work environments through, again, questionnaires. Both approaches have yet proved their effectiveness in forecasting or predicting incident occurrence. In fact, it seems to date no proven indicator, methodology or any mean are known to be capable of predicting the occurrence of incidents in a workplace (Chen and Yang, 2004). Chen and Yang (2004) who observed the deficiency of the studies in the literature, have developed a predictive risk indicator (PRI) based on unsafe acts or conditions in a petrochemical plant. The unsafe observation results are quantified by a simple rating based on estimates of probability of danger (PD), frequency of work exposure (FE), number of persons at risk (RN) and maximum of probable loss (MPL). The ratings are combined according to the geometric average to give the risk index.

As it can be seen from the studies mentioned above, problem of work system safety has been analyzed from different point of views in the literature. However, as stated by Chen and Yang (2004), the safety in a work system is always dynamic and depends not only on the perception of workers but also on many other complicating factors such as the management enforcement of safety regulations, worker's attitude toward safety, workplace ergonomics, etc. Work system safety management is a function of many factors (Grote and Künzler, 2000; Champoux and Brun, 2003; Fang et al., 2004; Mearns et al., 2003) and at the same time a factor of the work system could affect another factor. Moreover, there may be inter-relations among the factors of work system. For this reason, work system safety should be analyzed from a holistic point of view. The main difference of this study from the others in the literature is its modeling of work system safety problem in a holistic manner. Just as in this study, analytic network process (ANP), which is an extension of analytic hierarchy process (AHP) and allows analysis of complex systems, is used to determine the faulty behavior risk of the work system. Additionally, difficulties or limitations can be encountered many times while measuring the risk levels of work system factors. For example, it is not possible to measure qualitative factors such as safety culture, sensory adaptation, tendency of risky behavior, competition, management–worker relationships, exactly. Therefore, measuring qualitative factors by using fuzzy numbers instead of using crisp numbers helps both making decisions easier and obtain more realistic results. In this context, fuzzy ANP is used to determine the weights of factors/sub-factors which are required for computation of FBR in this study.

2. Fuzzy ANP calculation for FBR

An initial study identified the multi-criteria decision technique, known as the analytic hierarchy process (AHP), to be the most appropriate for solving complex decision-making problems (Yüksel and Dağdeviren, 2007). AHP was first introduced by Saaty (1980) and used in different decision-making process (Bozdağ et al., 2003; Kahraman et al., 2003, 2006; Tolga et al., 2005). The basic assumption of AHP is the condition of functional independence of the upper part, of the hierarchy, from all its lower parts, and from the criteria or items in each level. Many decision-making problems cannot be structured hierarchically because they involve interaction of various factors, with high-level factors occasionally depending on low-level factors (Saaty and Takizawa, 1986; Saaty, 1996). Saaty suggested the use of AHP to solve the problem of independence among alternatives or criteria, and the use of ANP to solve the problem of dependence among alternatives or criteria.