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A new approximation for risk assessment using the AHP and Fine Kinney methodologies

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ABSTRACT

The most important stage in the field of occupational health and safety is the assessment stage, where the risk point of each identified hazard is calculated, and a determination is made as to whether the hazard level is acceptable or unacceptable. In the field of risk assessment, the Fine Kinney method is commonly used in practice. The Analytical Hierarchy Process (AHP) might also be used as an efficient method in determining the importance levels of the hazards in risk assessment studies, but the AHP method does not determine whether the hazards are at an acceptable level based on their risk points. In this paper, a risk assessment study has been conducted in a large manufacturing company in which the hazards were determined based on experience, and the past 10 years' statistical records were categorized and each category has been prioritized using the AHP method. The hazards determined in the field have also been assessed using the Fine Kinney method. The relation between the assessment of the risk class in the Fine Kinney risk assessment and the AHP points has been examined and the risk class intervals for AHP have been determined. In the study, an approach has been developed based on the fact that the measure of the risk class in the Fine Kinney risk assessment method could be used with the results obtained using the AHP method; therefore, the importance levels and risk classes of the hazards might be able to be determined together with the AHP method.

1. Introduction

Occupational health and safety is a subject that has become increasingly important day by day as a result of society's reactions to and the monetary costs associated with occupational accidents and diseases. Studies of both the state and private operations and workers increase daily in the field of occupational health and safety.

The World Health Organization (WHO) and the International Labour Organization (ILO) have defined occupational health and safety as ensuring the adaptation of the work to the human and the each human to their work.

Hazard determination and risk assessment studies are an important element in occupational health and safety research. In OHSAS 18001, which is an international standard, risk has been defined as the combination of the results and occurrence probability of a determined hazardous event; moreover, risk assessment has been defined as the process of calculating the magnitude of the risk and deciding whether the risk is tolerable. Detecting the hazards before the damage occurs, determining the criticality levels and preparing the precautionary plans for each level are significant stages. The operations that make hazard detection and risk assessment important and that could manage this process successfully reduce both monetary and moral damages. As a practical matter, in the real world, a number of qualitative, quantitative and hybrid risk assessment methods are used.

Qualitative risk assessment methods include checklists, "what-if" analyses, safety audits, task analyses, the sequentially timed event plotting (STEP) technique and Hazard and Operability study (HAZOP). Quantitative risk assessment methods include the proportional risk-assessment (PRAT) technique (FMEA, Fine Kinney), the decision matrix risk-assessment (DMRA) technique, and weighted risk analysis (WRA). Hybrid techniques include Human Error Analysis Techniques, Fault-tree Analysis, Event Tree Analysis etc. (Marhavilas et al., 2011). In addition, the AHP method is another method commonly used as a risk assessment technique in practice (Padma and Balasubramanie, 2007; Yulong et al., 2008). Although some of these methods (such as AHP) yield only a risk score, other methods (such as Fine Kinney) yield risk scores and the risk classes of each hazard.

In the field of occupational health and safety, in addition to using risk assessment methodologies, there are many studies

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involving the determination of the importance degrees of hazards using the AHP method. Padma and Balasubramanie (2007) used the AHP method in their risk assessment study related to shoulder and neck pain. In that study, prioritizing the impact of different risk categories was conducted for pain in that particular region. Yulong et al. (2008) used the AHP method to assess the safety risks in the communication connections between satellite systems. Hui et al. (2012) examined the parameters of fire safety methods, general layout plans, building flammability, thermal insulation material and temporary fire control system using the AHP method applied to a system aiming to prevent fires. Aminbaksh et al. (2013) used the AHP method to sequence hazards based on their importance level at the stage of project risk assessment in the construction sector. Classification was made as the accident hazard, physical hazards and chemical hazards and the hazard elements in each group were assessed using the AHP method. Nefeslioglu et al. (2013) suggested using a modified AHP method in studies related to natural hazards (landslides, floods, etc.) regarding the protection of natural resources. Badri et al. (2013) studied risk assessment in underground mining projects in Quebec and conducted examinations using the AHP method to cover 250 potential hazards. Mabrouki et al. (2014) used the AHP method as a decision support methodology in their risk management studies in an airport terminal. The importance levels of the risk groups examined in all of these studies were sequenced using the AHP method, which means that the risk classes could not be determined.

Expressing the risks verbally based on personal views and value judgments rather than numerical magnitude leads to uncertainty. When there are no numerical data in some situations, verbal language and terms occur in risk assessment methods as fuzzy expressions. Due to this property of the risk assessment methods, the fuzzy AHP approach has been selected in several studies (Dagdeviren and Yuksel, 2008; Lavasani et al., 2011; Zhang and Zhong, 2011; Sofyalıoglu and Kartal, 2012; Zheng et al., 2012; Shi et al., 2012; Kant Sharma et al., 2012; Bao-Chun et al., 2013; Ganguly and Guin, 2013; Gao et al., 2014).

In some studies, different techniques have been used together with the AHP method, including Data Envelopment Analysis (DEA) (Wang et al., 2008), Vector Projection Method (Sharma and Gandhi, 2008), target programming (Arunraj and Maiti, 2010), and Backpropagation (BP) Neural Network (Jiang and Ruan, 2010). However, there are no studies using the Fine Kinney method integrated AHP.

In the literature, there are few studies undertaken using only the Fine Kinney risk assessment methodology. Babut et al. (2011) determined the pitfalls, advantages and limitations of the Fine Kinney methods. Oturakci et al. (2015) revised the values of the parameters of the Fine Kinney methods based on linear and square interpolation. Risk assessment is implemented in production and distribution of solar panels based on the revised values of parameters.

In all of these studies, determining the importance levels of the hazards with AHP has been studied frequently, and no study has been conducted regarding the issue of classifying hazards (i.e., at acceptable or unacceptable levels) and regarding which hazards should be prioritized under this classification. The present study seeks to fill this gap, and a hazard determination and risk assessment study was thus undertaken by the experts in a determined production field; the hazards so determined have been categorized, and each category has been scored using AHP. The hazard elements determined in the field have been scored using the Fine Kinney risk assessment method. The relation between the AHP scores and the classes in the Fine Kinney risk assessment method has been examined and class intervals have been determined for AHP scores. In this study, the class intervals from the Fine Kinney risk assessment method could be used in the results obtained using the AHP method, and it was therefore concluded that the AHP method could help determine not only the importance levels of hazards but also whether the hazard levels are acceptable and into which classes the hazards might be sorted.

2. Material and methods

The present study developed a new approximation based on the Fine Kinney and the AHP methods.

2.1. Fine Kinney risk assessment method

The Fine Kinney method is a quantitative risk assessment method derived from MIL-STD-882 standards and developed by Kinney and Wiruth in 1976. In this method, three parameters (likelihood, exposure and possible consequences) are considered for each detected hazard. Then, a "Risk Score" is obtained by multiplying these parameters, as shown in Eq. (1).

$$\begin{aligned}\text{Risk Score} = {} & \text{Likelihood of Hazardous Event} \\ & \times \text{The Exposure Factor} \\ & \times \text{Possible Consequence}\end{aligned} \tag{1}$$

The assessment tables for the concepts used to calculate the risk score are shown in Tables 1–3, and the risk score itself is shown in Table 4 (Kinney and Wiruth, 1976).

2.2. The analytic hierarchy process (AHP) method

The AHP method is commonly used among decision-reaching techniques. It was developed by Thomas Saaty from the University of Pittsburgh (Saaty, 1980). As per AHP methodology, the decision-reaching problem is first clearly defined, and then the target, main criteria, sub-criteria and alternatives are determined. Then, the interactions between the criteria and the alternatives are determined and a hierarchical structure is formulated. A comparison is made between the criteria and the applicable alternatives using the assessment scale shown in Table 5, and comparison matrices are formed (Saaty, 1980).

Next, the consistency ratio of each formed matrix must be calculated. Saaty's consistency ratio is defined as consistency index/random index. The random index is formulated based on the number of criteria (n). The consistency index (CI) is formulated based on Eq. (2), where λ_{max} is the largest eigenvalue of the considered matrix. The consistency ratio should be less than or equal to ten percent. If it is greater than ten percent, then the comparison matrix must be revised and the consistency ratio recalculated (Saaty, 1980).

$$\mathrm{CI} = \frac{\lambda_{max} - n}{n - 1} \tag{2}$$

The importance scores shown in the comparison matrices are used to assess the criteria and alternatives for the decision makers.

Table 1
The values for likelihood of hazardous event.

Likelihood	Value
Might well be expected	10
Quite possible	6
Unusual but possible	3
Only remotely possible	1
Conceivable but very unlikely	0.5
Practically impossible	0.2
Virtually impossible	0.1