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A new method for estimating human error probabilities: AHP–SLIM

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Abstract

Accidents in industrial settings are mainly a result of human errors (HEs); relevant fields that consider HEs have recently increased in number. For this reason, numerous methods to quantitatively estimate what is known as the HE probability (HEP) have been developed. However, it is difficult to obtain empirical data, which forces a heavy reliance on the judgment of experts in the field. During the process of judgments by experts, subjectivity plays an important role, causing difficulties in assuring consistency. To overcome this problem and to obtain a more accurate estimation, this study suggests a new and simple method. This method is referred to as AHP–SLIM, a type of HEP estimation using an analytic hierarchy process (AHP), which quantifies the subjective judgment and confirms the consistency of collected data. This new method also uses the process of expert judgment within the success likelihood index method (SLIM).

Keywords: Human error probability; Performance shaping factors; Expert judgment; Analytic hierarchy process; Success likelihood index method; Driver's error

1. Introduction

Human error (HE) is an important concern in the safe operation of nuclear power plants and other complex industrial establishments [1]. For example, in many major disasters, such as the Tenerife collision (1977) and the Three Mile Island accident (1979), HE was the crucial element involved in the incorrect operation of these high-risk systems [2]. To analyze and predict this probability (i.e. human error probability (HEP)) in these fields, human reliability analysis (HRA) is performed as part of a system safety analysis, in particular probabilistic safety assessment (PSA) of nuclear power plants [3]. There are various methods, such as technique for human error rate prediction (THERP), that are used during HRA [4]. Recently, there have been attempts to apply HRA to other assessment areas, including pharmaceutical and medical areas; service and business fields; low-technology risk fields; and socio-political decision-making areas [5]. A number of HRA techniques are closely related to these fields. These methods include absolute probability judgment (APJ) [5], success likelihood index method (SLIM) [6], and paired comparison (PC) [7], etc. They are frequently used to simplify the performance of HRA. They are also usually used during the preliminary application phase of HRA [5].

The ideal sources of HE data for these HRAs are empirical studies on human performance and accidents. Unfortunately, there is limited availability of such data [5]. This has led to reliance on assessments by experts, and this procedure has been used successfully in various areas [8]. However, several problems are associated with expert judgment for HRA. These problems can include inconsistencies of judgments and the difficulty in systematically considering performance shaping factors (PSFs), which are factors that influence human performance [4].

The problems related to the expert judgment in HRA can be summarized as follows: PC can check the consistency of experts; however, it is difficult to check the consistency of raw data for the judgments. It is also difficult when considering PSFs. The consistency check in APJ is done after all of the judgments are made. This implies that if there is a major inconsistency in the result, the experts must make new judgments. This method also has the issues related to the consideration of PSFs. Additionally, SLIM has problems while verifying consistency in a judgment stage. In contrast to these aforementioned methods, SLIM can consider PSFs; however, there

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can be the problem that the weights of the PSFs are independent of task (i.e., HE) ratings [9]. Additionally, in SLIM, a rating of HE is based on expert opinions concerning the PSFs in a real plant [6] or on the situation as it exists [10]. However, in cases of HE that may be difficult to know the present conditions of PSFs, the specific situations in which the HE would occur frequently must be assumed.

This paper suggests a new method, termed AHP–SLIM, that utilizes an analytic hierarchy process (AHP) and SLIM. The former process, which is a simple and widely used decision-making tool, is used to elicit the likelihood of failures of target tasks in this paper. The latter is used to convert the results of the AHP into HE probabilities (HEPs). Using this new method, previous problems can be overcome and HEPs can be estimated easily and quickly in various fields.

This paper is organized as follows: Section 2 describes AHP and SLIM briefly. The proposed method is explained in detail in Section 3, and its validation experiment is described in Section 4. Finally, Section 5 presents the conclusion.

2. Methods

2.1. AHP

The AHP developed by Saaty [11] is a multi-criteria decision method for complex problems, in which both qualitative and quantitative aspects are considered. There are many areas where AHP is applied, such as economics, flexible manufacturing systems and subjective probability estimation [12]. It has created a voluminous work of literature by various researchers; additionally, its mechanism is known to many experts.

The following is an outline of the steps used to carry out AHP:

(1) Break down the problem into a hierarchy of decision elements in order to develop a decision hierarchy (see Fig. 1).
(2) Produce judgment data by a pairwise comparison matrix of the decision elements. The numerical scale used for assigning values to these comparative ratings is shown in Table 1.
(3) Calculate the priority vector and check consistency of the matrix.
(4) Compute relative weights of the decision elements.
(5) Confirm consistency of the entire hierarchy.
(6) Sum the relative weights to obtain scores of the decision alternatives.

A detailed description of this method is given in [13].

AHP is based on a user's experience and judgment and its results are objective [11] and realistic [14]. In general, people are better at making relative comparisons as opposed to absolute judgments [2]; the creation of the relative comparisons is the basic principle behind AHP. An intrinsic and useful byproduct of AHP is an index of consistency, which provides information on the severity of the numerical and transitive consistency violations [13]. If consistency ratio (CR) suggested by Saaty [11] is above 0.1, the person making the judgment should seek additional information, re-examine the data used in constructing the scale, and then make a new judgment. However, it is not absolute standard and can be changed according to circumstances.

There have been a number of studies on the quantification of subjective judgment or the elicitation of subjective

Table 1
Scale of relative importance used in the pairwise comparisons of AHP

Comparative judgment	Scale of relative importance
T_i and T_j are equally important	1
T_i is moderately more important than T_j	3
T_i is strongly more important than T_j	5
T_i is very strongly more important than T_j	7
T_i is extremely more important than T_j	9
Intermediate values between two adjacent judgments	2, 4, 6, 8

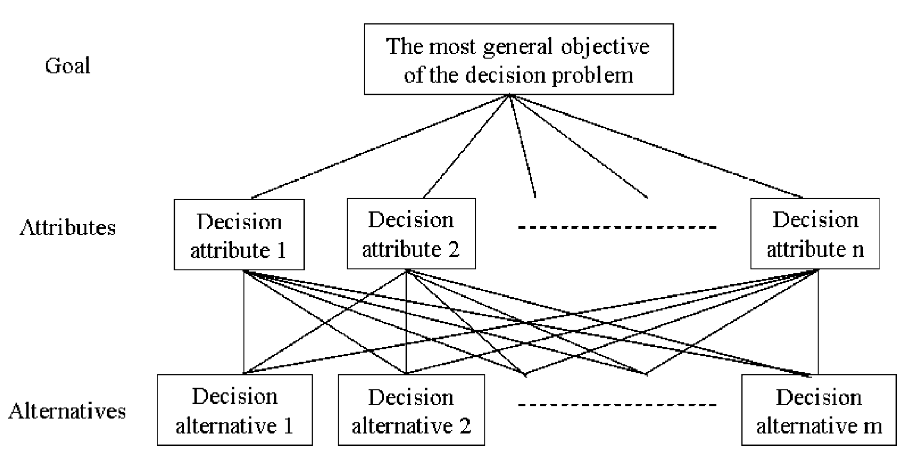

Fig. 1. An example form of decision elements in AHP [12].