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Multi-factorial risk assessment: An approach based on fuzzy preference relations

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Abstract

The main purpose of this paper is to develop a new method to aggregate the information given by several experts or criteria about different alternatives in order to obtain the preferred alternative or alternatives. This method has to take into account the interaction of the different alternatives and a parameter modelling the flexibility of this method has to be introduced. More precisely, this method uses fuzzy preference relations, aggregated by means of weighted ordered weighted averaging aggregation operators (WOWA). For the exploitation phase the extended weighted voting algorithm is introduced and studied in detail. Finally, the goodness of this approach is analyzed using it to combine different points of view (people, environment, assets and reputation impact for the company) in the assessment of risk associated with human reliability.

Keywords: Fuzzy preference relation; Aggregation function; WOWA operator; Group decision making problem; Risk assessment matrix

1. Introduction

Each year billions of dollars are spent to develop, manufacture, and operate transportation systems such as aircraft, ships, trains and motor vehicles throughout the world. During their operational life-time, thousands of lives are lost annually due to various types of accidents. For example, in the United States around 42 000 deaths occur annually due to automobile accidents only on highways [14]. In terms of dollars, in 1994 the total cost of motor vehicle crashes, was estimated to be around $150 billion to the United States economy [9,14].

In addition, between the 70% and 90% of transportation crashes are produced as a consequence of human error to a certain degree [14]. Moreover, human errors contribute significantly to many transportation crashes across all modes of transportation. For example, according to a National Aeronautics and Space Administration (NASA) study

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over 70% of airline accidents involved some degree of human error and according to a British study around 70% of railway accidents on four main lines during the period 1900–1997 were the result of human error [1,10,11]. Although the study of human reliability may be traced back to 1958, but since late 80s several hundreds of papers on human reliability have appeared. An interesting list can be found in the Appendix of the classical book of Dhillon [5].

A main topic related to human factors is the concept of risk assessment matrix (see [4,17]). It is considered useful for studying human reliability in general and human reliability in transportation systems in particular. The risk assessment matrix allows the classification of different kinds of errors according to their importance. This classification can help in decision making about the most important or urgent one.

Usually the risk matrix takes into account only one criterion (most of the cases: economical impact). However, decision making in a company often considers more than one. Therefore, it is interesting to consider at the same time more than one different risk matrix, each one associated with a different criteria for consequences (for example, effects on people, environment, assets or reputation).

Thus, a method to combine this information is needed, in order to classify the errors according to more than one criterion. This is our starting point. However, we have developed a general method to combine the information about different alternatives given by several experts or taking into account several criteria and the choice of the set of the best ones. This method can be applied in any environment where there exists interaction among the different alternatives or some experts are more reliable than others. This will be done by the definition of fuzzy preference relations and the use of different aggregation functions, in particular the weighted ordered weighted averaging operator.

Thus, firstly the general method is developed and later it is applied to the particular area we are interested in. In detail, the structure of this paper is as follows: Section 2 gives an overview of the preliminary definitions used in this article. In Section 3 the group decision making problem matter of this study and also the proposed method to solve it are presented and its behavior in accordance to the used parameter is studied. Section 4 shows our experimental framework and the experimental analysis carried out for the particular case of human reliability. We finish with some conclusions and open problems.

2. Preliminary definitions

In this section we carry out a brief introduction to fuzzy preference relations and aggregation operators. Firstly, we will introduce the type of fuzzy relations used in this work, together with some specific properties. Next, we will recall the definitions of aggregation operators and, in particular, the case of the non-weighted and weighted ordered weighted averaging aggregation operators.

2.1. Fuzzy preference relations

Initially, in group decision making decision making problems crisp relations are used to represent the presence or absence of preference between the different alternatives. However, in real problems, it is hard to measure the preference between two alternatives and, in some cases, we cannot unequivocally determine which one is preferred. That is the reason why this concept is generalized by introducing multivalued relations. This generalization allows us to measure the degree of preference to which an alternative is preferred to another. A general study about multivalued relations can be seen in [7].

There are different kind of multivalued or fuzzy relations, according to different ways of considering the available information. In particular we are interested in probabilistic relations (also known as reciprocal or ipsodual relations). In this paper, as there is no ambiguity, we will call them fuzzy preference relation.

Definition 1. Given a finite set of alternatives $\mathcal{A}$, a **fuzzy preference relation** P is a mapping $P : \mathcal{A} \times \mathcal{A} \to [0, 1]$ such that $P(a, b) + P(b, a) = 1$ for any pair of alternatives a and b in $\mathcal{A}$.

The fuzzy preference relation $P(a, b)$ between two alternatives a and b carries a bipolar semantic, meaning that the interval $[0, 1/2)$ represents preference of b over a, the interval $(1/2, 1]$ represents the preference of a over b and the central value $1/2$ represents indifference.