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Fuzzy logic modifications of the Analytic Hierarchy Process

Arnold F. Shapiro [a,*,1], Marie-Claire Koissi [b]

[a] Actuarial Science Program, Smeal College of Business, Penn State University, University Park, PA 16802, USA
[b] Actuarial Science Program, Department of Mathematics, University of Wisconsin-Eau Claire, Eau Claire, WI, 54701, USA

HIGHLIGHTS

- This article explores fuzzy logic versions of the Analytic Hierarchy Process (AHP).
- It begins with a review of main features of the AHP and its linguistic limitations.
- Then, the features of the three most commonly used fuzzy AHP models are examined.
- A risk assessment likelihood score example is used to illustrate the methodology.
- Possible actuarial and insurance applications of the fuzzy AHP are also presented.

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ABSTRACT

The Analytic Hierarchy Process (AHP) is a measurement methodology based on pair-wise comparisons that relies on judgment to derive priority scales. During its implementation, one constructs hierarchies, then makes judgments or performs measurements on pairs of elements with respect to a criterion to derive preference scales, which are then synthesized throughout the structure to select the preferred alternative.

One of the areas where the AHP finds application is in the subjective phases of risk assessment (RA), where it is used to structure and prioritize diverse risk factors, including the judgments of experts. Since fuzzy logic (FL) has been shown to be an effective tool for accommodating human experts and their communication of linguistic variables, there has been research aimed at modeling the fuzziness in the AHP (FAHP), and recently the focus of some of that modeling has been with respect to RA.

The literature discusses more than one FAHP model, which raises the question as to which are the prominent models and what are their characteristics. In response to this question, we examine three of the most influential FAHP models. The article proceeds as follows. It begins with a brief overview of the AHP and its limitations when confronted with a fuzzy environment. This is followed by a discussion of FL modifications of the AHP. A RA-based likelihood score example is used throughout. The article ends with a commentary on the findings.

Contents

* Corresponding author.
E-mail addresses: afs1@psu.edu (A.F. Shapiro), koissiml@uwec.edu (M. Koissi).

1 Much of this article was worked on while he held the Dr. L.A.H. Warren Chair in Actuarial Research, Warren Centre for Actuarial Studies and Research, University of Manitoba, Winnipeg, Canada.

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1. Introduction

The Analytic Hierarchy Process (AHP) (Saaty, 1980, 1999, 2008) is a measurement methodology based on pair-wise comparisons that relies on judgment to derive priority scales. During implementation of the AHP, one constructs hierarchies, then makes judgments or performs measurements on pairs of elements with respect to a criterion to derive preference scales, which are then synthesized throughout the structure to select the preferred alternative.

One of the areas[2] where the AHP finds application is in the subjective phases of risk assessment (RA). Depending on the decision-making context, however, problems can arise because decision-making often is hindered by data limitations and ambiguities, such as incomplete or unreliable data, and vague and subjective information owing to a reliance on human experts and their communication of linguistic variables. Since fuzzy logic (FL) is an effective tool in such circumstances, there has been considerable research based on adjusting the AHP for fuzziness (FAHP), and recently the focus of some of those studies has been in RA.

The examples of FAHP in RA generally have an engineering context. Zeng et al. (2007) and Nieto-Morote and Ruz-Vila (2011), for example, presented a FAHP-based RA methodology to cope with the multitude of risks associated with complicated construction projects, where FL and the AHP were used to deal with subjective judgments and to structure the large number of risks, respectively. In a safety context, Shi et al. (2012) use the FAHP to model RA associated with falling from height on construction projects, Fera and Macchiaroli (2010) used FAHP to develop a new RA model to address safety management of small and medium enterprises, and An et al. (2011) used FAHP to develop a RA system for evaluating both qualitative and quantitative risk data and information associated with the safety management of railway systems. Another application area was offshore drilling, where Miri Lavasani et al. (2011) used FAHP to estimate the weights required for grouping non-commensurate risk sources associated with the RA of oil and gas offshore wells, and Zhang et al. (2012) use FAHP to develop a RA model of relief wells to cope with potential accidents during onshore and offshore drilling.

The literature discusses more than one FAHP model, which raises the question as to which are the prominent models and what are their characteristics. In response to this question, we examine the models underlying three of the most influential FAHP articles, based on Google Scholar citations, van Laarhoven and Pedrycz (1983), Buckley (1985b) and Chang (1996). The article proceeds as follows. It begins with a brief overview of the AHP and its limitations when confronted with a fuzzy environment. This is followed with a discussion of FL modifications of the AHP. A RA-based likelihood score example is used throughout. The article ends with a commentary on the findings.

2. The hierarchical structure

We start with a discussion of the hierarchical structure since it is key to the study of the AHP. A simple representation of a hierarchical structure is the $K \times n$ version depicted Fig. 2.1,[3] where K and n denote the number of criteria and alternatives, respectively.

As indicated, this hierarchy consists of three levels: (Saaty and Vargas, 2012, p. 2)

- The goal of the decision at the top level,
- The criteria, which constrain the attainment of the goal, in the second level, and
- The alternatives, which are evaluated based on the criteria, are located in the third level.

2 Surveys of other areas of AHP applications can be found in Vargas (1990), Vaidya and Kumar (2006), Subramanian and Ramanathan (2012) and Saaty and Vargas (2012).

3 Adapted from Buckley (1985b, p. 238) Figure 1.