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Calibrated fuzzy AHP for current bank account selection

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ABSTRACT

Fuzzy AHP is a hybrid method that combines Fuzzy Set Theory and AHP. It has been developed to take into account uncertainty and imprecision in the evaluations. Fuzzy Set Theory requires the definition of a membership function. At present, there are no indications of how these membership functions can be constructed. In this paper, a way to calibrate the membership functions with comparisons given by the decision-maker on alternatives with known measures is proposed. This new technique is illustrated in a study measuring the most important factors in selecting a student current account.

1. Introduction

Despite the popularity and simplicity of the Analytic Hierarchy Process (AHP), it is often criticised for its inability to adequately handle the uncertainty of a decision maker's preferences. In classic AHP, the judgements are represented by exact values on a scale of 1–9 (Saaty, 1977, 1980). However, in many real cases, the linguistic assessments of human evaluations are often vague, and it is not realistic to represent them with crisps values. To overcome these shortcomings, fuzzy AHP has been developed to take into account this uncertainty and imprecision. It is essentially the combination of two methods: fuzzy set theory and AHP (Van Laarhoven & Pedrycz, 1983). Fuzzy set theory requires the definition of a membership function for each verbal judgement. However, in all papers reviewed, there was no indication of how the membership functions have been selected. This paper proposes a way to calibrate the membership functions with comparisons given by the decision-maker on alternatives with known measures. In this case, we asked to compare the surface of geometrical figures and as a result, the membership function was personalised for each participant. Then, the fuzzy AHP with the customised membership functions is applied to a case study in order to establish the most important factors in the selection of a student current account. We found that service is the most weighted criteria when selecting a bank account.

2. Fuzzy AHP

Fuzzy AHP was first proposed by Van Laarhoven and Pedrycz (1983) and is an extension of AHP combined with fuzzy set theory (Zadeh, 1965). The main advantage of this combination is that it makes allowances for the vagueness and imprecision of human preference. The key idea is that a certain degree of an element belongs to a fuzzy membership set, which is given by a function depicted on a two-axis diagram. The horizontal axis consists of the domain elements of the fuzzy sets and the vertical axis the degree of membership on a scale of 0–1. These membership functions can take several shapes: linear, S-curves, triangular or trapezoidal representations. In practice, triangular and trapezoidal membership functions are the most frequently used. They can be denoted by $\tilde{A} = (l, m_l, m_u, u)$, where $l \leqslant m_l \leqslant m_u \leqslant u$ correspond to lower, modal-lower, modal-upper and upper bound, i.e. the trapezium's angle points. If the membership is triangular, then $m_l = m_u$ (Fig. 1). The membership of $\tilde{A}$ is defined by:

$$\mu_{\tilde{A}}(x) = \begin{cases} \frac{x-l}{m-l}, & l \leqslant x \leqslant m \\ 1, & x = m \\ \frac{u-x}{u-m}, & m < x < u \\ 0, & otherwise \end{cases} \quad (1)$$

Fuzzy AHP is based on 4 steps:

(a) For each linguistic term of the evaluation scale, a membership function is constructed.
(b) Criteria/alternatives are pair-wise compared in comparison matrix $\tilde{A}$

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2n} \\ \dots & \dots & \dots & \dots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & \tilde{a}_{nn} \end{bmatrix} \quad (2)$$

where $\tilde{a}_{ij}$ is the fuzzy comparison between criterion/alternative i and j.

(c) Fuzzy priorities are derived from comparison matrix $\tilde{A}$. This is done using the eigenvalue method (3) or any other method used in traditional AHP (Ishizaka & Labib, 2011)

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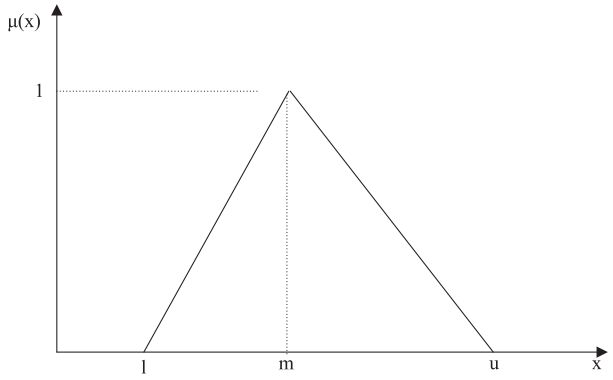

Fig. 1. Trapezoidal membership function.

$$\widetilde{A} \cdot \tilde{p} = \lambda \cdot \tilde{p} \tag{3}$$

(d) As these fuzzy priorities must be ranked, they need to be translated into real numbers to make the ranking more obvious than fuzzy numbers. Several methods exist including the weighted average approach, the centre of area, the mean-max membership and the first (or last) of maxima. The most popular is the centre of area or centroid (Van Leekwijck & Kerre, 1999).

Except for the fuzzy representation of the judgement scale, the steps of fuzzy AHP are the same as traditional AHP (Ishizaka & Labib, 2011). Therefore, this paper will concentrate on the fuzzy membership function that represents the judgement scale. In the literature review, we found 27 different representations of fuzzy membership functions (Table 1), however none have been justified. Li and Kuo (2008) are the only one to ask the decision-maker to construct their own membership function but do not give any guidance on how to fulfil this task. This paper presents a new way to construct a personalised membership function. The methodology will be illustrated by a case study in banking.

3. Membership function calibration

The calibration of the membership function is performed through a comparison of measurable alternatives. In our case, we used geometrical figures but it is possible for other items to be used (Fig. 2). The participants were asked to compare their surface with the verbal scale given in Table 2. They were also informed that the figures were in an increasing order, so the questionnaire only had one scale direction (Table 3), e.g. A is necessarily smaller than B. Not all comparisons are required for the calibration; therefore only a subset was asked to avoid overwhelming the participants. The measured pairwise comparisons of the figures are given in Table 4.

The verbal judgements (Table 3) given by the decision-maker are matched with the real values (Table 4). For example, suppose that the decision-maker evaluates a "very strong" difference between figures G and A, D and A and also between Fig. I and B. The real values of these three evaluations (i.e. 7, 4, 4.5) are entered into the matching table (Table 5). Therefore, it can be deduced that the decision maker values outcomes of between 4.5 and 7 as "very strong".

All the judgements matched with the real measures are entered into a Table 5. For each verbal judgement, the minimal, mean and maximal values are calculated. They correspond to the angle points of the customised membership function. Fig. 3 represents the customised membership functions of all verbal judgements. Notice that these membership functions are not similar (e.g. the wideness of the membership function "very strong" is much larger than "moderate") because they depend on the person's interpretation of verbal judgements.

4. Case study

4.1. Introduction

The development of an appealing product may have a long-term impact on the profitability of companies. This is especially true in the banking sector, where students often remain with the same bank when they leave education. Students are not a profitable segment of the market because their income is low, however they are the potentially high earner in the future. As a result, it is in the best interests of the bank to attract and retain these customers early.

This explorative study will give an insight into the most important criteria in selecting a student bank account using calibrated fuzzy AHP, described in Section 3.

4.2. Criteria description

In the literature there are several studies for bank selection in different countries: Romania (Katircioglu, Tumer, & Kılınç, 2011a); Ghana (Hinson, Owusu-Frimpong, & Dasah, 2011; Mahmoud, Tweneboah-Koduah, & Danku, 2011); USA (Lee & Marlowe, 2003), Northern Cyprus (Katircioglu, Unlucan, & Dalci, 2011b; Safakli, 2007); Malaysia (Ahmad, Rustam, & Dent, 2011; Amin, 2008; Mokhlis, Salleh, & Mat, 2011); Greece (Lymperopoulos, Chaniotakis, & Soureli, 2006); Bahrain (Al-Ajmi, Abo Hussain, & Al-Saleh, 2009; Almossawi, 2001); United Kingdom (Devlin & Gerrard, 2005; Farquhar & Panther, 2008; Thwaitesa & Verea, 1995); Singapore (Ta & Har, 2000), Poland (Kennington, Hill, & Rakowska, 1996); Hong Kong (Denton & Chan, 1991); India (Gupta & Dev, 2012). Each study has its own list of criteria. As the utilisation of AHP becomes difficult with a large number of criteria, similar factors were grouped together (Table 6) and structured into a hierarchy (Fig. 4). This also avoids the problem of overweighting dependent criteria (e.g. internal and external bank appearance).

Some criteria have not been considered because:

- They are out-dated, for example, ATM service. Banks have a consensus scheme to share ATM information systems, therefore; a person can withdraw cash either free of charge or for a small fee from any ATM belonging to another bank.
- They are outside the control of the banks, such as recommendations from friends and relatives. Some studies also suggest that these criteria are negligible in bank account selection (Almossawi, 2001; Ta & Har, 2000).

4.3. Demography of the participants

Forty participants of the University of Portsmouth were recruited in a sample of equal gender and nationality proportions (Table 7).

Participants are aged between 19 and 30 (Table 8). Twenty-three students are on a bachelor course and 17 on a master's level course. Only participant P36 had full-time work experience of more than six months.

4.4. Questionnaire collection mode

To increase the response rate, different collection channels were used:

- **E-mail**: This collection mode has a low associated cost (no printing and postage) and is timesaving as a large population can be targeted at once. The questionnaire was sent to 75 students. Twenty-five questionnaires were returned but only 14 were correctly completed. The perceived disadvantage of this