Research Article

Enhancing Human Resource Management System with Triangular Fuzzy Weighted Bonferroni Mean Operator

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Abstract: Organizations require an efficient human resource management system to manage employee-related matters such as attendance, leave, salaries, and training. The effectiveness of a business relies on how well it manages its human resources. To achieve this, it is important to have a reliable HR management system in place. Therefore, it is necessary to conduct a study on the factors that influence the selection of an HR management system. To gather multiple decision-makers' opinions and account for their interactions, the Bonferroni mean method is commonly used. In dealing with imprecise and uncertain data, triangular fuzzy numbers are used as a more flexible alternative to crisp numbers. This study used the triangular fuzzy weighted Bonferroni mean operator to rank the primary factors for selecting such a system. The five factors considered were human resource functions (C1), technology (C2), software quality (C3), cost (C4), and vendor support system (C5), with input from four decision makers. Based on their opinions, the study found that human resource functions (C1) were considered the most important factor, followed by vendor support (C5), software quality (C3), cost (C4), and technology (C2).

Keywords: triangular fuzzy set; Bonferroni mean operator; human resource.

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1. INTRODUCTION

Human resource (HR) has been widely known as the workers who make up the workforce of companies, or organisations. The HR department is in charge of all aspects related to employment, including salaries, training, and recruiting, among other things. Consequently, HR management is essential for a company's success and growth. However, HR management is typically complicated when done manually without the assistance of a system, particularly for large and growing businesses (Boon, Den & Lepak, 2019). Generally, a company that aims to grow needs to have a HR management system in order to view and manage human and resources as a whole.

The selection of HR management system is influenced by a number of factors. First is the human resource functions that are accessible in the HR management system (Esangbedo et al., 2021; Fenech Baguant, & Ivanov, 2019). This includes employee information management, organization structure management, compensation and benefits, training management, recruiting management and performance management. Second, the technology employed is compatible with the current information technology trend (Vrontis et al., 2022). The current technological trend includes, among other things, the ability to perform big data analysis (BDA), artificial intelligence (AI), the internet of things (IoT), self-service, and the ability to connect to social networks such as Whatsapp, Telegram, Facebook, Instagram, and LinkedId (Awotunde et al., 2022). The third factor is software quality, which can vary depending on its functionality, dependability, usability, maintainability, and portability (Hassan, Hussain & Irfan, 2019; Shameem et al., 2020; Esangbedo et al., 2021). The fourth major factor is the cost incurred during the development and running of the HR management system (Boon, Den & Lepak, 2019). This includes the costs of upkeep, licensing, consultation, equipment, and software training. Last but not least, the system's vendor support (Zeebaree Syukur & Hussan, 2019; Pillai & Sivathanu, 2020). This denotes the support the vendor provides after the software has been purchased. The things that need to be considered are vendor reputation, technological capability, after-sales service commitment, and service response time.

When selecting an HR management system, there are several factors that must be carefully considered, making it a challenging decision to make. This study utilizes multi-criteria decision making tools to analyze the multiple interactive criteria involved. The Bonferroni mean aggregation operator is commonly used to address the interaction between decision makers. Pamucar (2020) researched the Bonferroni mean and Dombi operator using interval grey numbers, while Wang and Li (2020) combined the Bonferroni mean and Power operator in a Pythagorean fuzzy environment. Tanriverdi, Ecer, and Durak (2022) proposed the use of the triangular fuzzy Dombi-Bonferroni operator in the BMW method to evaluate the factors affecting airport selection during the COVID-19 pandemic. Their study employs a triangular fuzzy set, which is the most basic form of fuzzy sets, utilizing three elements of the membership function, including the smallest value, the most likely value, and the largest possible value. The concept of the triangular fuzzy set has been further enhanced in recent years with the integration of other mathematical concepts. For instance, Fang et al. (2023) combined the triangular fuzzy set with a single valued neutrosophic set in the MCDM method to select the next successor of a family business. Similarly, Yue, Zou, and Hu (2023) proposed a new theory that involves the use of the triangular fuzzy set and intuitionistic fuzzy set to solve two-sided matching problems. In another study, Hu et al. (2023) introduced several aggregation operators based on the triangular fuzzy set and ordered weighted averaging operator.

Even though the use of triangular fuzzy set has been explored to a more complicated version, the traditional triangular fuzzy set is still relevant, and it suits most of the fuzzy decision making problems. In addition, the factors influencing the purchase of an HR management system are numerous and difficult to decide with our limited human rational thinking. As a result, the triangular fuzzy weighted Bonferroni mean operator is used to rank the factors in this study. This study only considers five major factors: HR functions (C1), technology (C2), software quality (C3), cost (C4), and vendor support system (C5). This research would be useful for companies looking for the primary criteria for selecting the best human resource management system.

2. METHOD & MATERIAL

In this section, we describe some basic concepts of triangular fuzzy set, Bonferroni mean operator of TFS, the triangular fuzzy linguistic scale and the defuzzification formula.

Definition 1. (Van Laarhoven & Pedrycz, 1983) A triangular fuzzy set $\tilde{A}$ is a triplet element (l, m, u). The membership function $u_{\tilde{A}}$ is defined as:

$$u_{\tilde{A}} = \begin{cases} 0 & x < l \\ \dfrac{x-l}{m-l} & l \le x \le m \\ \dfrac{x-u}{m-u} & m \le x \le u \\ 0 & x \ge u \end{cases} \tag{1}$$

where $0 < l \le m \le u$, *l*, *m* and *u* are the lower, modal and upper values of $\tilde{A}$, respectively. Next, the definition of triangular fuzzy weighted Bonferroni mean is given below:

Definition 2. (Zhu et al., 2015) Let $\tilde{A}_i = (l_i, m_i, u_i)(i = 1,2,...,n)$ be the triangular fuzzy sets and $p,q > 0$, $w_i = (w_1, w_2, ..., w_n)^T$ is the weight vector of $\tilde{A}_i = (l_i, m_i, u_i)(i = 1,2,...,n)$ where w_i indicates the importance degree of $\tilde{A}_i$, satisfying $w_i > 0$ and $\sum_{i=1}^{n} w_i = 1$. If

$$TFWBM_{w_i}^{p,q}\left(\tilde{A}_1, \tilde{A}_2, ..., \tilde{A}_n\right) = \left(\frac{1}{n(n-1)} \sum_{\substack{i,j=1 \\ i \ne j}}^{n} \left(w_i \tilde{A}_i\right)^p \left(w_j \tilde{A}_j\right)^q \right)^{1/p+q} \tag{2}$$

then the obtained $TFWBM_{w_i}^{p,q}$ is called the triangular fuzzy weighted Bonferroni mean (TFWBM) operator. Table 1 shows the linguistic triangular fuzzy scale used in this study.

Table 1. The linguistic triangular fuzzy scale

Linguistic terms	Influence score	Triangular Fuzzy Set
Very Low (VL)	1	(0,0,0.25)
Low (L)	2	(0,0.25,0.5)
Medium (M)	3	(0.25,0.5,0.75)
High (H)	4	(0.5,0.75,1)
Very High (VH)	5	(0.75,1,1)

The fuzzy averaging concept was used in this study as a defuzzification method. The following definition illustrates the defuzzification method used in this study.

Definition 3. (Bojadziev and Bojadziev, 2007) Let $\tilde{A} = (l, m, u)$ be a triangular fuzzy set and the defuzzification of $\tilde{A}$ is as follows:

$$A = \frac{l + 2m + u}{4}$$

where *A* is a real number, also known as crisp number.

The flowchart of the proposed methodology is given below:

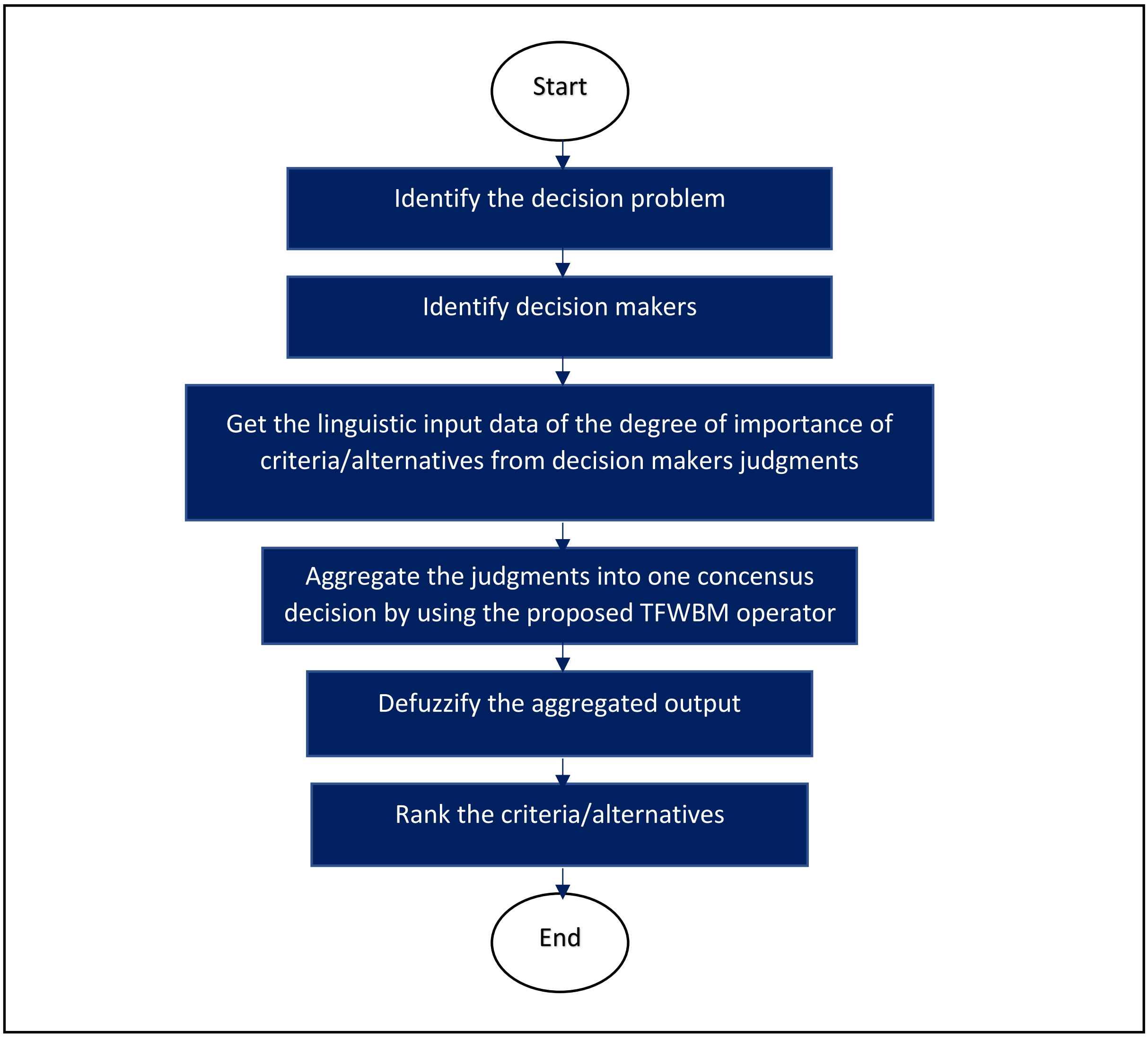

Figure 1. Flowchart of the research methodology

3. APPLICATION, RESULTS & DISCUSSION

The proposed method is applied to a decision problem adapted from Esangbedo et al., (2021). In the selection of human resource management system, there are 5 main criteria that need to be considered. They are human resource function (C1), Technology (C2), Software Quality (C3), Cost (C4) and Vendor Support (C5). The weight of each criterion is given as $(0.2, 0.1, 0.3, 0.4)^T$. In this study, the triangular fuzzy weighted Bonferroni mean is employed to rank to identify the primary criterion in selecting the human resource management system. Four decision makers are asked to weigh in on the relative importance of each criterion. Table 2 displays the linguistic data collected from the four decision makers.

Table 2. The linguistic data (Esangbedo et al., 2021)

	DM 1	DM 2	DM 3	DM 4
C1	VH	H	H	H
C2	VL	H	VL	L
C3	H	H	VL	H
C4	L	L	H	L
C5	L	L	H	H

Then, the data in Table 2 is transformed into the triangular fuzzy information based on the linguistic scale conversion in Table 1.

Table 3. The fuzzy data and analysis

	DM 1	DM 2	DM 3	DM 4	AGGREGATED DECISION	CRISP VALUE
C1	(0.75,1,1)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.25, 0.5, 0.75)	(0.102, 0.164, 0.212)	0.161
C2	(0,0,0.25)	(0.25, 0.5, 0.75)	(0,0,0.25)	(0, 0.25, 0.5)	(0, 0.029, 0.094)	0.038
C3	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0,0,0.25)	(0.25, 0.5, 0.75)	(0.038, 0.076, 0.14)	0.083
C4	(0, 0.25, 0.5)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	(0, 0.25, 0.5)	(0.0, 0.076, 0.138)	0.073
C5	(0, 0.25, 0.5)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	(0.25, 0.5, 0.75)	(0.035, 0.098, 0.159)	0.097

The aggregated decision is obtained by Eq. (2). The calculation to get the aggregated decision for C1 is illustrated below:

Let $\tilde{A}_{11}$ be the triangular fuzzy number of C1 obtained from DM 1, $\tilde{A}_{12}$ be the triangular fuzzy number of C1 obtained from DM 2, $\tilde{A}_{13}$ be the triangular fuzzy number of C1 obtained from DM 3, $\tilde{A}_{14}$ be the triangular fuzzy number of C1 obtained from DM 4 and $\tilde{A}_{1}$ be the aggregated triangular fuzzy number of C1. Therefore,

$$\tilde{A}_{11} = \left(0.75, 1, 1\right);\ \tilde{A}_{12} = \left(0.25, 0.5, 0.75\right);\ \tilde{A}_{13} = \left(0.5, 0.75, 1\right);\ \tilde{A}_{14} = \left(0.25, 0.5, 0.75\right)$$

$$\tilde{A}_1 = TFWBM_{w_i}^{p,q}\left(\tilde{A}_{11}, \tilde{A}_{12}, \tilde{A}_{13}, \tilde{A}_{14}\right) = \left(\frac{1}{n(n-1)}\sum_{\substack{i,j=1\\ i\neq j}}^{n}\left(w_i\tilde{A}_i\right)^p\left(w_j\tilde{A}_j\right)^q\right)^{1/p+q}$$

$$= \left(\frac{1}{4(3)}\left(\begin{array}{l}\left(w_1\tilde{A}_1\right)^1\left(w_2\tilde{A}_2\right)^1 + \left(w_1\tilde{A}_1\right)^1\left(w_3\tilde{A}_3\right)^1 + \left(w_1\tilde{A}_1\right)^1\left(w_4\tilde{A}_4\right)^1 + \left(w_2\tilde{A}_2\right)^1\left(w_3\tilde{A}_3\right)^1 + \left(w_2\tilde{A}_2\right)^1\left(w_4\tilde{A}_4\right)^1 \\ + \left(w_3\tilde{A}_3\right)^1\left(w_4\tilde{A}_4\right)^1 + \left(w_2\tilde{A}_2\right)^1\left(w_1\tilde{A}_1\right)^1 + \left(w_3\tilde{A}_3\right)^1\left(w_1\tilde{A}_1\right)^1 + \left(w_4\tilde{A}_4\right)^1\left(w_1\tilde{A}_1\right)^1 + \left(w_3\tilde{A}_3\right)^1\left(w_2\tilde{A}_2\right)^1 + \\ \left(w_4\tilde{A}_4\right)^1\left(w_2\tilde{A}_2\right)^1 + \left(w_4\tilde{A}_4\right)^1\left(w_3\tilde{A}_3\right)^1\end{array}\right)\right)^{1/2}$$

The lower membership function, l is given as follow:

$$= \left(\frac{1}{4(3)}\left(\begin{array}{l}\left(w_1 l_1\right)^1\left(w_2 l_2\right)^1 + \left(w_1 l_1\right)^1\left(w_3 l_3\right)^1 + \left(w_1 l_1\right)^1\left(w_4 l_4\right)^1 + \left(w_2 l_2\right)^1\left(w_3 l_3\right)^1 + \left(w_2 l_2\right)^1\left(w_4 l_4\right)^1 \\ + \left(w_3 l_3\right)^1\left(w_4 l_4\right)^1 + \left(w_2 l_2\right)^1\left(w_1 l_1\right)^1 + \left(w_3 l_3\right)^1\left(w_1 l_1\right)^1 + \left(w_4 l_4\right)^1\left(w_1 l_1\right)^1 + \left(w_3 l_3\right)^1\left(w_2 l_2\right)^1 + \\ \left(w_4 l_4\right)^1\left(w_2 l_2\right)^1 + \left(w_4 l_4\right)^1\left(w_3 l_3\right)^1\end{array}\right)\right)^{1/2}$$

$$= \left(\frac{1}{12} \begin{pmatrix} 0.0006 + 0.0015 + 0.0023 + 0.0008 + 0.0012 + 0.0032 \\ +0.0006 + 0.0015 + 0.0023 + 0.0008 + 0.0012 + 0.0032 \end{pmatrix} \right)^{1/2}$$

$$= 0.102 .$$

The modal membership function, *m* and the upper membership function *u* can be calculated in the same way and get (0.102, 0.164, 0.212). Based on the crisp value obtained in Table 3, the criteria can be ranked in descending order, $C1 > C5 > C3 > C4 > C2$. The obtained ranking reveals that the most important factor is the human resource functions (C1), followed by vendor support (C5), software quality (C3), cost (C4) and technology (C2). The first and last ranks are comparable to the findings of Esangbedo et al. (2021). They used the full consistency method (FUCOM) and taking into account the same criteria.

4. CONCLUSION

As a conclusion, this paper combines the triangular fuzzy set into Bonferroni mean operator to identify the ranking of main factors towards the selection of an HR management system. Human resources are important in any organisation, company, or institution, regardless of industry. This is especially important if the business requires more humans than machines. The primary factors in selecting an HR management system were ranked in this study. The HR functions are the most important factor. As a result, before purchasing an HR management system, authorities must first investigate the functions that the system provides. It should cover all aspects of employee management. This study is significant because it will help authorities and stakeholders choose the best human resource management system.

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