Sakarya University Journal of Science

ISSN : 2147-835X
Publisher : Sakarya University

Vol.28, No. 4, 685-696, 2024
DOI: https://doi.org/10.16984/saufenbilder.1226636

Research Article

A Novel Correlation Measurement Method for Multi-Attribute Decision-Making Problems Based on Double Hierarchy Hesitant Fuzzy Linguistic Evaluation and Player Assignment Application in Football

Veysel Çoban

Bilecik Seyh Edebali University, Faculty of Engineering, Department of Industrial Engineering, Bilecik, Türkiye, veysel.coban@bilecik.edu.tr

ARTICLE INFO

Keywords:
Double hierarchy hesitant fuzzy linguistic term set
Multi-Attribute decision making
Correlation coefficient
Footballsport

Article History:
Received: 30.12.2022
Accepted: 14.06.2024
Online Available: 01.08.2024

ABSTRACT

Linguistic expressions are widely used to reflect the decision maker's evaluations more easily and clearly in the decision-making problems, The Double Hierarchy Hesitant Fuzzy Linguistic Term Set (DHHFLTS), an extension of linguistic expressions, helps the decision maker to reflect their hesitant evaluations in complex decision making problems using two different sets of linguistic terms. Correlation measurements are used as an important tool in making decisions by making comparative evaluations in complex decision making problems based on common criteria. In this study, a new method is proposed to improve the existing correlation measurement method using DHHFLTSs. The proposed method aims to increase the reflective power of hesitant thoughts in the evaluation process by including fuzzy linguistic expressions in the calculation process. In order to prove the validity of the proposed method, the original problem of choosing the most suitable player for the positions in football sport is considered as a Multi-Attribute Decision Making (MADM) problem. Correlation values and assignment results obtained from the proposed method are compared with the current method values. Consistency of results and values between methods reveals the validity of the proposed method.

1. Introduction

The increase in factors in decision-making problems causes complexity in the evaluation and calculation processes of the problem. Evaluation of alternatives with their increasing features and factors leads to the emergence of Multi-Attribute Decision Making (MADM) problems [1]. Linguistic information is applied to meet the quantitative expressions that are insufficient in making evaluations in MADM problems. The fuzzy linguistic approaches proposed by Zadeh [2] for expressing and measuring linguistic information differ according to the characteristics of decision-making methods.

The Double Hierarchy Linguistic Term Set (DHLTS) is an important extension of fuzzy linguistic approaches and consists of two sets of linguistic terms that support each other [3]. In order to reflect the hesitancies of decision makers in the DHLTS evaluation, the Double Hierarchy Hesitant Fuzzy Linguistic Term Set (DHHFLTS) is developed as an extension of DHLTS [4]. Similarity and distance measurements developed based on Double Hierarchy Unstable Fuzzy Linguistic Elements (DHHFLE) provide new methods and applications for DHHFLTSs [5]. DHHFLTs find an important application area especially in decision making problems and provide new approaches to classical methods [4, 6–9].

Correlation coefficient measurement, which is an important measurement tool in reflecting the strength of the linear relationship between two quantitative variables [10, 11], is used as an important solution method in decision making problems based on DHHFLE and DHHFLTS [3,

Cite as: V. Çoban (2024). A Novel Correlation Measurement Method for Multi-Attribute Decision-Making Problems Based on Double Hierarchy Hesitant Fuzzy Linguistic Evaluation and Player Assignment Application in Football, *Sakarya University Journal of Science*, 28(4), 685-696. https://doi.org/10.16984/saufenbilder.1226636

12]. The determination of correlation values based on fuzzy information is carried out on the basis of statistics and information energy calculation [11, 13]. While statistical-based correlation calculation defines the relationship between variables in the [-1,1] range, the correlation value calculated with less data based on information energy is defined in the [0,1] range.

The first correlation calculation studies for fuzzy membership functions [14] are extended for fuzzy, heuristic fuzzy and hesitant fuzzy sets [13, 15]. The extension of the application area enables the development of correlation coefficient calculations for hesitant fuzzy sets and double hierarchy hesitant fuzzy sets [16, 17]. The use of linguistic information, which is evaluated in terms of information entropy, in correlation measure constitutes an important field of study [18]. In this context, correlation calculations based on information energy are used in hesitant fuzzy sets [19], hesitant fuzzy linguistic terms [20] and dual hesitant fuzzy sets [15].

Identifying and directing talents in sports is an important step in achieving athletic success. Achieving success in team sports depends on positioning the player in the game position that best suits their characteristics and abilities [21]. Achieving success in football depends on determining the relationship between the characteristics of the field positions and the skills of the players [22]. Assigning the most suitable player to positions under these multiple attributes emerges as a multi-attribute decision-making problem. Evaluation of players and positions and assignment of players according to field positions are decided by qualitative evaluations based on the knowledge and experience of the coaches.

DHHFLTS is an appropriate evaluation method in defining the characteristics and expectations of players and positions in player selection problems based on linguistic evaluation. Correlation coefficient measurements based on DHHFLTS are identified as an important decision-making tool in reflecting the fit between player and position based on assessments with DHHFLTS. Fuzzy linguistic expressions are directly converted to classical values by calculating the degree of membership in the current correlation measurement application based on DHHFLTSs. This method prevents adequately reflecting the hesitancies of the linguistic assessments in the correlation calculations. Elimination of this drawback in the current method constitutes the main motivation of the study.

This study proposes a new correlation coefficient measurement model that integrates linguistic assessments into calculations with primary and secondary definition values of DHHFLTSs. The validity and applicability of the model is observed by considering the player selection problem in football, which is a novel MADM problem for DHHFLTSs evaluations. The case study aims to measure the correlation coefficient between the skills of the players and needs of the positions that are defined by DHHFLTS and to assign the most suitable player to the field positions. The proposed method and application case study constitute the original features of the study.

The organization of the study is as follows: Section 2 mentions the basic definitions of DHLTS and DHHFLTS and explains their arithmetic operations. In Section 3, DHHFLTS-based covariance, variance and correlation coefficient measurement models are discussed. Section 4 describes the original model proposed for the development of the current model based on DHHFLTS. Section 5 deals with the player selection problem to prove the validity of the proposed method and the results are compared with the current methods. The conclusion section, Section 6, makes an overall assessment based on the study results and makes recommendations for future studies.

2. Preliminaries

Linguistic terms, which are an important evaluation tool in complex decision making problems, are extended with fuzzy linguistic terms so that the decision maker's evaluations can be expressed more easily and clearly [23]. This section discusses extensions of linguistic term sets that incorporate decision-makers' assessments in detail and hesitancies.

2.1. Double hierarchy linguistic term sets

DHLTS consists of two hierarchical structures as the primary hierarchy being the primary linguistic term set (LTS) and the secondary hierarchy describing the primary linguistic term set [4]. DHLTS was developed to provide a detailed description of linguistic considerations expressed using the Hesitant Fuzzy Linguistic Term Set (HFLTS) [3], [23]. $S=\{s_t \mid t=-\tau,\ldots,-1,0,1,\ldots,\tau\}$ first hierarchy LTS and $O^t=\{o_t^k \mid k=-\varsigma,\ldots,-1,0,1,\ldots,\varsigma\}$ is the second hierarchy LTS of s_t, the mathematical definition of DHLTS is as follows:

$$S_O = s_{t\langle o_k \rangle} \mid t = -\tau, \ldots, -1,0,1, \ldots, \tau; k = -\varsigma, \ldots, -1,0,1, \ldots, \varsigma\} \quad (1)$$

in the equation $s_{t\langle o_k \rangle}$ is defined as DHLT, and o_k defines different degrees of the linguistic term s_t. Figure 1 shows the semantic distribution of DHLTS for $\tau = 3$ and $\varsigma = 3$. The second hierarchy LTS of the first hierarchy linguistic term s_1 is defined as $O^1=\{o_k^1 \mid k=-3,-2,-1,0,1,2,3\}$ [24].

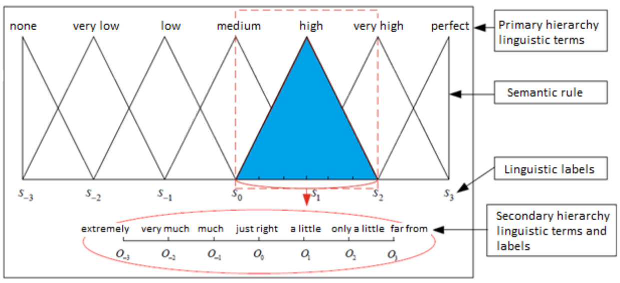

Figure 1. Definition of a linguistic term in LTS in the primary hierarchy with the secondary hierarchy LTS [24]

According to the t value of the first hierarchy LTS, the order and expressions of the secondary hierarchy LTS change. For example, if $t \geq 0$ in Figure 1, the second hierarchy LTS is in ascending order ($O^{t\geq 0}=\{o_{-3}$ = far from, o_{-2} = only a little, o_{-1} = a little, o_0 = just right, o_1=much, o_2 = very much, o_3 = extremely$\}$), while if $t \leq 0$ the LTS of the second hierarchy decreases ($O^{t\leq 0}=\{o_{-3}$ = extremely, o_{-2} = very much, o_{-1} = much, o_0 = just right, o_1 =a little, o_2 = only a little, o_3 = far from$\}$). Also, when $t=\tau$, the second hierarchy is $O=\{o_k \mid k=-\varsigma,\ldots,-1,0\}$ of LTS, while $t=-\tau$, the second hierarchy is considered the $O=\{o_k \mid k=0, 1,\ldots, \varsigma\}$ part of LTS [5, 8].

2.2. Double hierarchy hesitant fuzzy linguistic term sets

DHHFLTS, which emerged as an extension of DHLTS, takes into account the hesitations of experts in the evaluation process in the decision-making process [4]. The mathematical expression of DHHFLTS defined in X, with S_O being DHLTS, is as follows:

$$H_{S_O} = \{\langle x_i, h_{S_O}(x_i)\rangle \mid x_i \in X\} \quad (2)$$

in the equation Double Hierarchy Hesitant Fuzzy Linguistic Element (DHHFLE) $h_{S_O}(x_i)=\{s_{\phi_{l\langle o_{\varphi_l}\rangle}}(x_i) \mid s_{\phi_{l\langle o_{\varphi_l}\rangle}} \in S_O;\ l=1,\ldots,L;\ \phi_l=-\tau,\ldots 0,\ldots,\tau;\ \varphi_l=-\varsigma,\ldots,0,\ldots,\varsigma\}$ denotes the possible degree of linguistic variable from x_i to S_O. L denotes the number of DHLTs in $h_{S_O}(x_i)$. The envelopment method of DHHFLEs provides a more comfortable understanding of DHHFLTS [24]. Functions that perform the conversion of continuous DHLTSs defined as $\bar{S}_O=\{s_{\phi_{l\langle o_{\varphi_l}\rangle}}(x_i) \mid \phi_l \in [-\tau,\tau\}, \varphi_l \in [-\varsigma,\varsigma]\}$ to real numbers (f) and returning ϕ_l and φ_l of the DHLT equivalent to γ_l membership degree (f^{-1}) are defined as follows [24]:

$$f: [-\tau,\tau] \times [-\varsigma,\varsigma] \to [0,1], f(\phi_l, \varphi_l) = \frac{\varphi_l + (\tau+\phi_l)\varsigma}{2\tau\varsigma} = \gamma_l \quad (3)$$

$$f^{-1}: [0,1] \to [-\tau,\tau] \times [-\varsigma,\varsigma], f^{-1}(\gamma_l) \quad (4)$$

The calculations of the transformation function, $f^{-1}(\gamma_l)$ according to the values of the membership degree (γ_l) are as follows [12, 24]:

- if γ_l =1 then $f^{-1}(\gamma_l)=s_{\tau\langle o_0\rangle}$
- if $1 \leq 2\tau\gamma_l-\tau < \tau$ then $f^{-1}(\gamma_l) = s_{[2\tau\gamma l-\tau]\langle o_{\varsigma(2\tau\gamma l-\tau-[2\tau\gamma l-\tau])}\rangle}$
- if $-1 \leq 2\tau\gamma_l-\tau \leq 1$ then $f^{-1}(\gamma_l) = s_{0\langle o_{\varsigma(2\tau\gamma l)}\rangle}$
- if $-\tau \leq 2\tau\gamma_l-\tau \leq -1$ then $f^{-1}(\gamma_l) = s_{[2\tau\gamma l-\tau]+1\langle o_{\varsigma(2\tau\gamma l-\tau-[2\tau\gamma l-\tau]-1)}\rangle}$
- if γ_l=-1 then $f^{-1}(\gamma_l) = s_{-\tau\langle o_0\rangle}$

HFEs and Hesitant Fuzzy Sets (HFS) consist of membership degrees defined for DHHFLEs. The transformations between DHHFLE (h_{S_O}) and HFE (h_γ) are calculated with the functions F and F^{-1}, respectively [6, 24]:

$$F(h_{S_O}) = F\left(\left\{s_{\phi_{l\langle\varphi_l\rangle}} \middle| s_{\phi_{l\langle\varphi_l\rangle}} \in S_O; l = 1,..,L; \phi_l \in [-\tau,\tau]; \varphi_l \in [-\varsigma,\varsigma]\right\}\right) = \{\gamma_l | \gamma_l = f(\phi_l,\varphi_l)\} = h_\gamma \quad (5)$$

$$F^{-1}(h_\gamma) = F^{-1}(\{\gamma_l | \gamma_l \in [0,1]; l = 1,..,L\}) = \left\{s_{\phi_{l\langle\varphi_l\rangle}} \middle| \phi_{l\langle\varphi_l\rangle} = f^{-1}(\gamma_l)\right\} = h_{S_O} \quad (6)$$

3. Correlation Calculation for DHHFLTS

The correlation coefficient is an important evaluation tool that defines the size and direction of the relationship between two variables [11]. Extended correlation coefficient calculations with fuzzy methods help to make the most appropriate matches in complex decision making problems [25]. This section discusses the correlation calculation method based on DHHFLTS defined by hesitant fuzzy linguistic evaluations.

Correlation coefficient calculations are made based on the means of DHHFLE and the mean and variances of DHHFLTS by considering the degree of hesitancy, which is an important indicator in the evaluation process [26]. DHLTS $S_O=\{s_{t\langle o_k\rangle} \mid t=-\tau,\ldots,0,\ldots,\tau;\ k=-\varsigma,\ldots,0,\ldots,\varsigma\}$ defined for DHHFLE, h_{S_O} and the mean, $\bar{h}_{S_O}$ and the hesitancy degree, $\eta(h_{S_O})$ are calculated as [24, 26]:

$$\bar{h}_{S_O} = f^{-1}\left(\frac{1}{L}\sum_{l=1}^{L} f(\phi_l,\varphi_l)\right) \quad (7)$$

$$\eta(h_{S_O}) = \sqrt{\frac{1}{L}\sum_{l=1}^{L}\left(f(\phi_l,\varphi_l) - \frac{1}{L}\sum_{l=1}^{L} f(\phi_l,\varphi_l)\right)^2} \quad (8)$$

Example 1: The average and hesitancy degrees of $h^1_{S_O} = \left\{s_{0\langle o_{-1}\rangle}, s_{1\langle o_0\rangle}, s_{2\langle o_{-2}\rangle}\right\}$ and $h^2_{S_O} = \left\{s_{-2\langle o_2\rangle}, s_{-1\langle o_1\rangle}, s_{0\langle o_{-3}\rangle}\right\}$ DHHFLEs, including DHLTS $S_O = \left\{s_{t\langle o_k\rangle} \middle| t \in [-3,3]; k \in [-3,3]\right\}$, are calculated as follows:

$\bar{h}^1{}_{S_O} = f^{-1}(1/3\ (4/9+2/3+13/18)) = s_{0\langle 2\rangle}$

$\bar{h}^2{}_{S_O} = f^{-1}(1/3\ (5/18+7/18+1/3)) = s_{-1\langle 0\rangle}$

$$\eta(h^1_{S_O}) = \sqrt{\frac{1}{L_1}\sum_{l=1}^{L_1}\left(f(\phi^1_l,\varphi^1_l) - \frac{1}{L_1}\sum_{l=1}^{L_1} f(\phi^1_l,\varphi^1_l)\right)^2} = 0.120$$

$$\eta(h^2_{S_O}) = \sqrt{\frac{1}{L_2}\sum_{l=1}^{L_2}\left(f(\phi^2_l,\varphi^2_l) - \frac{1}{L_1}\sum_{l=1}^{L_2} f(\phi^2_l,\varphi^2_l)\right)^2} = 0.045$$

The means and hesitancy degrees of DHHFLEs, $h^1_{S_O}$ and $h^2_{S_O}$ are calculated as $s_{0\langle 2\rangle}$ and $s_{-1\langle 0\rangle}$ and 0.120 and 0.045, respectively. Considering the Euclidean distance between DHHFLEs, the correlation coefficient between two DHHFLTSs $(H^1_{S_O}, H^2_{S_O})$ is calculated as [24, 27]:

$$\rho(H^1_{S_O}, H^2_{S_O}) = \frac{C(H^1_{S_O}, H^2_{S_O})}{\sqrt{Var(H^1_{S_O})}\sqrt{Var(H^2_{S_O})}} = \frac{\sum_{i=1}^{n}\left[\frac{1}{L^i_1}\sum_l^{L^i_1} f(\phi^i_{l1},\varphi^i_{l1}) - \bar{H}^1_{S_O}\right]\left[\frac{1}{L^i_2}\sum_l^{L^i_2} f(\phi^i_{l2},\varphi^i_{l2}) - \bar{H}^2_{S_O}\right]}{\sqrt{\left(\sum_{i=1}^{n}\left(\frac{1}{L^i_1}\sum_l^{L^i_1} f(\phi^i_{l1},\varphi^i_{l1}) - \bar{H}^1_{S_O}\right)^2\right)\left(\sum_{i=1}^{n}\left(\frac{1}{L^i_2}\sum_l^{L^i_2} f(\phi^i_{l2},\varphi^i_{l2}) - \bar{H}^2_{S_O}\right)^2\right)}} \quad (9)$$

in the equation, the denominator defines the square root of the product of the variances of the hesitant sets, and the variance of $\bar{H}^1_{S_O}$ DHHFLTS is calculated as [4, 24]:

$$Var(H_{S_O}) = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n}\left(\frac{1}{L^i_1}\sum_l^{L^i_1} f(\phi^i_{l1},\varphi^i_{l1}) - \bar{H}_{S_O}\right)^2\right)} \quad (10)$$

in the equation, $\bar{H}_{S_O}$ defines the mean of DHHFLTS and is calculated as [24]:

$$\bar{H}_{S_O} = F^{-1}\left(\frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{L^i}\sum_l^{L^i} f(\phi^i_l,\varphi^i_l)\right)\right) \quad (11)$$

The correlation value between the DHHFLTSs $(H^1_{S_O}, H^2_{S_O})$ is expected to meet the basic Pearson correlation coefficient conditions. The expected conditions are as follows [12]:

- $\rho\left(H_{S_O}^1, H_{S_O}^2\right) = \rho\left(H_{S_O}^2, H_{S_O}^1\right)$
- $\rho\left(H_{S_O}^1, H_{S_O}^1\right) = 1$
- $-1 \leq \rho\left(H_{S_O}^1, H_{S_O}^2\right) \leq 1$

Example 2: In calculating the correlation coefficient between $H_{S_O}^{\ 1}$ and $H_{S_O}^{\ 2}$ DHHFLTS defined in $S_O = \{s_{t\langle o_k\rangle} \,|\, t\in[-3,3];\ k\in[-3,3]\}$ DHLTS, firstly, the membership degrees of each DHHFLTS elements are calculated using Equation 3.

$$H_{S_O}^{\ 1} = \left\{ \begin{matrix} \left\{s_{0\langle o_{-2}\rangle}, s_{1\langle o_0\rangle}, s_{2\langle o_{-1}\rangle}\right\}, \\ \left\{s_{1\langle o_1\rangle}, s_2\right\}, \left\{s_{1\langle o_{-3}\rangle}, s_{2\langle o_2\rangle}, s_{3\langle o_{-2}\rangle}\right\} \end{matrix} \right\}$$

$$H_{S_O}^{\ 2} = \left\{ \begin{matrix} \left\{s_{-1\langle o_0\rangle}\right\}, \left\{s_{-2\langle o_3\rangle}, s_{-1\langle o_{-2}\rangle}, s_{0\langle o_2\rangle}\right\}, \\ \left\{s_{1\langle o_0\rangle}, s_{2\langle o_{-3}\rangle}, s_{3\langle o_{-1}\rangle}\right\} \end{matrix} \right\}$$

f_{11}^1 =7/18, f_{12}^1 =2/3, f_{13}^1 =13/18, $\bar{f}_1^1$ =(1/3 (7/8+2/3+13/18))=16/27

f_{21}^1 =13/18, f_{22}^1 =5/6, $\bar{f}_2^1$ =(1/2 (13/18+5/6)) =7/9

f_{31}^1 =1/2, f_{32}^1 =17/18, f_{33}^1 =8/9, $\bar{f}_3^1$ =(1/3 (1/2+17/18+8/9))=7/9

$\bar{H}_{S_O}^{\ 1}$ =(1/3 (16/27+7/9+7/9))=58/81

f_{11}^2 =1/3, f_{12}^2 =1/2, f_{13}^2 =1/2, $\bar{f}_1^2$ =(1/3 (1/3+1/2+1/2))=4/9

f_{21}^2 =1/3= $\bar{f}_2^2$

f_{31}^2 =2/3, f_{32}^2 =2/3, $\bar{f}_3^1$ =(1/2 (2/3+2/3))=2/3

$\bar{H}_{S_O}^{\ 2}$ =(1/3 (4/9+1/3+2/3))=13/27

The covariance between DHHFLTSs is calculated as [12, 24]:

$$C\left(H_{S_O}^1, H_{S_O}^2\right) = \frac{1}{n}\left(\sum_{i=1}^{n}\left[\frac{1}{L_1^i}\sum_{l}^{L_1^i} f\left(\phi_{l1}^i, \varphi_{l1}^i\right) - \bar{H}_{S_O}^1\right]\left[\frac{1}{L_2^i}\sum_{l}^{L_2^i} f\left(\phi_{l2}^i, \varphi_{l2}^i\right) - \bar{H}_{S_O}^2\right]\right) \quad (12)$$

The covariance value between $H_{S_O}^1, H_{S_O}^2$ is calculated according to Equation 12 as follows:

$C\left(H_{S_O}^1, H_{S_O}^2\right)$ =1/3((16/27-58/81)(4/9-13/27) + (7/9-58/81)(1/3-13/27)+(7/9-58/81)(2/3-13/27)) = 0.0023

The variation values of the DHHFLTSs are obtained as (Eq. 10).

$Var\left(H_{S_O}^1\right)$ =√(1/3 ((16/27-58/81)^2+(7/9-58/81)^2+(7/9-58/81)^2))=0.0076

$Var\left(H_{S_O}^2\right)$ =√(1/3 ((4/9-13/27)^2+(1/3-13/27)^2+(2/3-13/27)^2))=0.0192

The correlation coefficient value between DHHFLTSs ($H_{S_O}^1, H_{S_O}^2$) is calculated according to Equation 9 as follows:

$\rho\left(H_{S_O}^1, H_{S_O}^2\right)$=0.0023/√(0.0076*0.192)=0.1890

The correlation result shows weak positive correlation between $H_{S_O}^1$ and $H_{S_O}^2$ DHHFLTS.

When attributes are defined with different weights in Multi-Attribute Decision Problems (MADM), the correlation coefficient between DHHFLTSs is found by including attribute weights in the calculations [24]. The weight of each element in the DHHFLTS defined in $S_O = \{s_{t\langle o_k\rangle} \,|\, t\in[-\tau,\tau],\ k\in[-\varphi,\varphi]\}$ is $w_i\in[0,1]$ and the weights of the elements are defined as $w = \{w_1, w_2, \ldots, w_n\}^T$ and $\sum_{i=1}^{n} w_i = 1$. The correlation coefficient between DHHFLTSs ($H_{S_{O_1}}, H_{S_{O_2}}$) based on the weighted hesitancy degree is calculated as follows [12, 24]:

$$\rho_w\left(H_{S_O}^1, H_{S_O}^2\right) = \frac{C_w\left(H_{S_O}^1, H_{S_O}^2\right)}{\sqrt{Var_w\left(H_{S_O}^1\right)}\sqrt{Var_w\left(H_{S_O}^2\right)}} = \frac{\sum_{i=1}^{n}\left[\frac{w_i}{L_1^i}\sum_l^{L_1^i} f\left(\phi_{l1}^i, \varphi_{l1}^i\right) - \bar{H}_{S_O}^{1w}\right]\left[\frac{w_i}{L_2^i}\sum_l^{L_2^i} f\left(\phi_{l2}^i, \varphi_{l2}^i\right) - \bar{H}_{S_O}^{2w}\right]}{\sqrt{\left(\sum_{i=1}^{n}\left(\frac{w_i}{L_1^i}\sum_l^{L_1^i} f\left(\phi_{l1}^i, \varphi_{l1}^i\right) - \bar{H}_{S_O}^{1w}\right)^2\right)\left(\sum_{i=1}^{n}\left(\frac{w_i}{L_2^i}\sum_l^{L_2^i} f\left(\phi_{l2}^i, \varphi_{l2}^i\right) - \bar{H}_{S_O}^{2w}\right)^2\right)}} \quad (13)$$

in the equation, the weighted mean ($\bar{H}_{S_O}^w$) and weighted variance ($Var_w\left(H_{S_O}\right)$) for DHHFLTSs ($H_{S_O}^1, H_{S_O}^2$) are defined, respectively, as follows [24]:

$$\bar{H}_{S_O}^w = F^{-1}\left(\frac{1}{n}\sum_{i=1}^{n}\left(\frac{w_i}{L^i}\sum_l^{L^i} f\left(\phi_l^i, \varphi_l^i\right)\right)\right) \quad (14)$$

$$Var_w\left(H_{S_O}\right) = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n}\left(\frac{w_i}{L_1^i}\sum_l^{L_1^i} f\left(\phi_{l1}^i, \varphi_{l1}^i\right) - \bar{H}_{S_O}^w\right)^2\right)} \quad (15)$$

If weights are not defined for DHHFLEs, the elements are assumed to be equally weighted and the weighted correlation coefficient (p_w) calculation is reduced to the normal correlation calculation (p). The conditions provided by the weighted correlation coefficient (p_w) are as follows [12]:

- $\rho_w\left(H_{S_O}^1, H_{S_O}^2\right) = \rho_w\left(H_{S_O}^2, H_{S_O}^1\right)$
- $\rho_w\left(H_{S_O}^1, H_{S_O}^1\right) = 1$
- $-1 \leq \rho_w\left(H_{S_O}^1, H_{S_O}^2\right) \leq 1$

Example 3: If the weight values of the x_i attributes of $H_{S_O}^1$ and $H_{S_O}^2$ DHHFLTS in Example 2 are defined as w= $(0.2, 0.5, 0.3)^T$, the weighted mean values $\bar{H}_{S_O}^{1w}$ =0.247 and $\bar{H}_{S_O}^{2w}$=0.152, variation values $Var_{w\left(H_{S_O}^1\right)}$=0.123 and $Var_w\left(H_{S_O}^2\right)$=0.0022, covariation value $C_{w\left(H_{S_O}^1, H_{S_O}^2\right)}$=0.0032 and the correlation coefficient value is calculated as $\rho_{w\left(H_{S_O}^1, H_{S_O}^2\right)}$=0.616. According to the results of Example 2, the direction of the relationship does not change, but its size increases.

4. New Correlation Coefficient Measurement Proposal for DHHFLTSS

The proposed method aims to continue the correlation coefficient calculation process on real linguistic terms rather than the direct use of membership degrees of DHHFLTSs. The method performs aggregation operations on primary and secondary linguistic terms of linguistic term sets and obtains new DHHFLEs. Covariance, variance and correlation coefficient calculations are made by calculating the membership degrees of the obtained DHHFLEs.

S_O is DHLTS and the aggregation operations of primary and secondary hierarchical degrees of DHHFLEs, $h_{S_O}(x_i)$ ={$s_{\phi_{l\langle o_{\varphi_l}\rangle}}$($x_i$) | $s_{\phi_{l\langle o_{\varphi_l}\rangle}} \in$ S_O; l=1,…,L; ϕ_l=-τ,…0,…,τ; φ_l=-ς,…,0,…,ς} of DHHFLTS defined in X and the combined DHHFLTS definitions are applied as follows:

$$\phi' = \frac{1}{L}\sum_{l=1}^{L}\phi_l \text{ and } \varphi' = \frac{1}{L}\sum_{l=1}^{L}\varphi_l \quad (16)$$

$$\dot{h}_{S_O} = \cup_{s_{\phi_{l\langle o_{\varphi_l}\rangle}} \in h_{S_O}}\left\{s_{\phi'_{\langle o_{\varphi'}\rangle}} \middle| \phi' \leq \tau; \varphi' \leq \varsigma\right\} \quad (17)$$

in the equation, L represents the number of DHLTs in $h_{S_O}(x_i)$. The covariance ($C\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right)$), variance ($Var\left(\dot{H}_{S_O}\right)$) and correlation coefficient ($\rho'\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right)$) among the combined DHHFLEs obtained from DHHFLTSs ($\dot{H}_{S_O}^1$,$\dot{H}_{S_O}^2$) are calculated as follows:

$$C\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right) = \frac{1}{n}\left(\sum_{i=1}^{n}\left[f\left(\left(\phi'^i_1, \varphi'^i_1\right) - \bar{\dot{H}}_{S_O}^1\right)\right]\left[f\left(\left(\phi'^i_2, \varphi'^i_2\right) - \bar{\dot{H}}_{S_O}^2\right)\right]\right) \quad (18)$$

$$Var\left(\dot{H}_{S_O}\right) = \sqrt{\frac{1}{n}\left(\sum_{i=1}^{n}\left(f\left(\left(\phi'^i, \varphi'^i\right) - \bar{\dot{H}}_{S_O}\right)\right)^2\right)} \quad (19)$$

$$\rho'\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right) = \frac{C\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right)}{\sqrt{Var\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right)}}$$

$$= \frac{\sum_{i=1}^{n}\left[f\left(\left({\phi'}_1^i,{\varphi'}_1^i\right)-\bar{\dot{H}}_{S_O}^1\right)\right]\left[f\left(\left({\phi'}_2^i,{\varphi'}_2^i\right)-\bar{\dot{H}}_{S_O}^2\right)\right]}{\sqrt{\left(\sum_{i=1}^{n}\left(f\left(\left({\phi'}_1^i,{\varphi'}_1^i\right)-\bar{\dot{H}}_{S_O}^1\right)\right)^2\right)\left(\sum_{i=1}^{n}\left(f\left(\left({\phi'}_2^i,{\varphi'}_2^i\right)-\bar{\dot{H}}_{S_O}^2\right)\right)^2\right)}} \quad (20)$$

in the equation, the mean of DHHFLTS, $\bar{\dot{H}}_{S_O}$, is defined as:

$$\bar{\dot{H}}_{S_O} = \left(\frac{1}{n}\sum_{i=1}^{n}{\phi'}^i, \frac{1}{n}\sum_{i=1}^{n}{\varphi'}^i\right) \quad (21)$$

The proposed method meets the basic Pearson correlation coefficient conditions, and the conditions for DHHFLTSs $(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2)$ are expressed as:

- $\rho'\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right) = \rho'\left(\dot{H}_{S_O}^2, \dot{H}_{S_O}^1\right)$
- $\rho'\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^1\right) = 1$
- $-1 \leq \rho'\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right) \leq 1$

If the attributes are weighted, the weighted correlation coefficient calculation method for DHHFLTSs $(H_{S_{O_1}}, H_{S_{O_2}})$ is recommended as follows:

$$\rho'_w\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right) = \frac{C_w\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right)}{\sqrt{Var_w\left(\dot{H}_{S_O}^1, \dot{H}_{S_O}^2\right)}} = \frac{\sum_{i=1}^{n}\left[w_i f\left(\left({\phi'}_1^i,{\varphi'}_1^i\right)-\bar{\dot{H}}_{S_O}^1\right)\right]\left[w_i f\left(\left({\phi'}_2^i,{\varphi'}_2^i\right)-\bar{\dot{H}}_{S_O}^2\right)\right]}{\sqrt{\sum_{i=1}^{n}\left(w_i f\left(\left({\phi'}_1^i,{\varphi'}_1^i\right)-\bar{\dot{H}}_{S_O}^1\right)\right)^2 \sum_{i=1}^{n}\left(w_i f\left(\left({\phi'}_2^i,{\varphi'}_2^i\right)-\bar{\dot{H}}_{S_O}^2\right)\right)^2}} \quad (22)$$

The basic correlation coefficient conditions provided by the proposed weighted method (p'_w) are as follows:

- $\rho'_w\left(H_{S_O}^1, H_{S_O}^2\right) = \rho'_w\left(H_{S_O}^2, H_{S_O}^1\right)$
- $\rho'_w\left(H_{S_O}^1, H_{S_O}^1\right) = 1$
- $-1 \leq \rho'_w\left(H_{S_O}^1, H_{S_O}^2\right) \leq 1$

The proposed method is applied in the case study and its application steps are explained in the Section 5. The validity of the method is proved by comparing with the current method.

5. Case Study: Assignment of Players to The Positions in Football

Identifying the right player in the right position, which ensures success in team games, cannot be done with mathematical calculations [22]. The assignment of the player to the position takes place with the expertise gained from the experience and observations of the coaches [28]. This case study aims to identify and assign the most suitable players for goal, defender, midfielder and forward football positions according to their physical, technical and mental characteristics [22, 29]. The skills required for the positions and the level of players to have these skills are defined by the expert coach with DHHFLTs. The most suitable player for the position is selected based on the highest level of correlation with the position requirements. The proposed correlation coefficient method based on the DHHFLTS is used to define the fit between positions and players. The positive and highest correlation coefficient value (∈ [-1,1]) defines the player most suitable for the position.

The basic skills used in determining the relationship between the position and the football players are defined in the main titles as physical, mental and technical. Characteristics of basic skills are as follows [22, 29, 30]:

- Physical: speed, agility, jumping, acceleration, height, strength
- Mental: ability to read the game, leadership, creativity, calmness, courage, belief in decision
- Technical: finishing, passing, shooting, heading, tackle, dribbling.

The basic skills expected for the positions are as follows [22, 29, 30]:

- Goal: height, reflex, high jump, flexibility, balance, playmaking
- Defender: strong physics, effectiveness in airballs, speed, move timing, passing ability
- Midfield: ability to read the game, passing ability, ball control, possession of the ball, calmness
- Forward: shooting, power, passing ability, speed, ball efficiency, ball control, reading the game.

Table 1. Double hierarchy linguistic expressions of expected properties for positions

	Physical	Mental	Technical
Goal	only a little good	far from very good	between a little medium and a little very good
Defender	between only a little very good and a little perfect	just right good	between good and far from perfect
Midfielder	only a little good	between a little very good and far from perfect	just right very good
Forward	between very much good and only a little perfect	between extremely medium and very much very good	a little very good

The case study aims to assign four player (A_1, Burak; A_2, Mehmet; A_3, Servet; A_4, Umut) candidates to four game positions (R_1,Goal; R_2,Defense; R_3,Midfielder; R_4,Forward) based on three general characteristics (P_1, Physical; P_2, Mental; O_3,Technical). The primary (S) and secondary (O) hierarchical LTSs of DHHLTS, H_{S_O}={⟨x_i, $h_{(S_O)}(x_i)$⟩| x_i∈X} defined in X used in DHHFLEs, $h_{S_O}(x_i)$={$s_{\phi_{l\langle o_{\varphi_l}\rangle}}$ (x_i)|$s_{\phi_{l\langle o_{\varphi_l}\rangle}}$∈$S_O$; l=1,…,L; ϕ_l=-τ,…0,…,τ; φ_l=-ς,…,0,…,ς} to define the position and characteristics of the players are as follows.

S={s_{-3}= none, s_{-2}= very bad, s_{-1}= bad, s_0= medium, s_1= good, s_2= very good, s_3= perfect}

O^-= {o_{-3}= extremely, o_{-2}= very much, o_{-1}= much, o_0= just right, o_1= a little, o_2= only a little, o_3= far from; $\phi_l \leq 0$}

O^+= {o_{-3}= far from, o_{-2}= only a little, o_{-1}= a little, o_0= just right, o_1= much, o_2= very much, o_3= extremely; $\phi_l \geq 0$}

Table 2. Double hierarchy linguistic expressions of player skills

	Physical	Mental	Technical
Burak	between far from medium and only a little medium	between a little medium and a little good	just right good
Mehmet	much very good	between very much medium and extremely very good	between just right good and far from perfect
Servet	between only a little medium and good	only a little perfect	between medium and extremely good
Umut	extremely very good	between extremely medium and a little very good	between good and perfect

Table 3. Definition position properties with DHHFLTS and transformations to HFLTEs

	Physical	Mental	Technical	Physical	Mental	Technical
Goal	$\{s_{1\langle o_{-2}\rangle}\}$	$\{s_{2\langle o_{-3}\rangle}\}$	$\{s_{0\langle o_{-1}\rangle}, s_1, s_{2\langle o_{-1}\rangle}\}$	$\{s_{1\langle o_{-2}\rangle}\}$	$\{s_{2\langle o_{-3}\rangle}\}$	$\{s_{1\langle o_{-1}\rangle}\}$
Defender	$\{s_{2\langle o_{-2}\rangle}, s_{3\langle o_{-1}\rangle}\}$	$\{s_{1\langle o_0\rangle}\}$	$\{s_{1\langle o_0\rangle}, s_2, s_{3\langle o_{-3}\rangle}\}$	$\{s_{2,5\langle o_{-1,5}\rangle}\}$	$\{s_{1\langle o_0\rangle}\}$	$\{s_{2\langle o_{-3}\rangle}\}$
Midfielder	$\{s_{1\langle o_{-2}\rangle}\}$	$\{s_{2\langle o_{-1}\rangle}, s_{3\langle o_{-3}\rangle}\}$	$\{s_{2\langle o_0\rangle}\}$	$\{s_{1\langle o_{-2}\rangle}\}$	$\{s_{2,5\langle o_{-2}\rangle}\}$	$\{s_{2\langle o_0\rangle}\}$
Forward	$\{s_{1\langle o_2\rangle}, s_2, s_{3\langle o_{-2}\rangle}\}$	$\{s_{0\langle o_3\rangle}, s_1, s_{2\langle o_2\rangle}\}$	$\{s_{2\langle o_{-1}\rangle}\}$	$\{s_{2\langle o_0\rangle}\}$	$\{s_{1\langle o_{2,5}\rangle}\}$	$\{s_{2\langle o_{-1}\rangle}\}$

Table 4. Definition player skills with DHHFLTS and transformations to HFLTEs

	Physical	Mental	Technical	Physical	Mental	Technical
Burak	$\{s_{0\langle o_{-3}\rangle}, s_{0\langle o_{-2}\rangle}\}$	$\{s_{0\langle o_{-1}\rangle}, s_{1\langle o_{-1}\rangle}\}$	$\{s_{1\langle o_0\rangle}\}$	$\{s_{0\langle o_{-2,5}\rangle}\}$	$\{s_{0,5\langle o_{-1}\rangle}\}$	$\{s_{1\langle o_0\rangle}\}$
Mehmet	$\{s_{2\langle o_1\rangle}\}$	$\{s_{0\langle o_2\rangle}, s_1, s_{2\langle o_3\rangle}\}$	$\{s_{1\langle o_0\rangle}, s_2, s_{3\langle o_{-3}\rangle}\}$	$\{s_{2\langle o_1\rangle}\}$	$\{s_{1\langle o_{2,5}\rangle}\}$	$\{s_{2\langle o_{-1,5}\rangle}\}$
Servet	$\{s_{0\langle o_{-2}\rangle}, s_{1\langle o_0\rangle}\}$	$\{s_{3\langle o_{-2}\rangle}\}$	$\{s_{0\langle o_0\rangle}, s_{1\langle o_3\rangle}\}$	$\{s_{0,5\langle o_{-2}\rangle}\}$	$\{s_{3\langle o_{-2}\rangle}\}$	$\{s_{0,5\langle o_3\rangle}\}$
Umut	$\{s_{2\langle o_3\rangle}\}$	$\{s_{0\langle o_3\rangle}, s_1, s_{2\langle o_{-1}\rangle}\}$	$\{s_{1\langle o_0\rangle}, s_2, s_{3\langle o_0\rangle}\}$	$\{s_{2\langle o_3\rangle}\}$	$\{s_{1\langle o_1\rangle}\}$	$\{s_{2\langle o_0\rangle}\}$

The application steps of the proposed correlation coefficient measurement method based on DHHFLTS are as follows:

Step 1. The skill characteristics expected for the positions and the characteristics of the players are defined in Table 1 and Table 2, respectively, using hesitant linguistic expressions.

Step 2. The linguistic domains defined in Table 1 and Table 2 are transformed to the DHHFLTSs in Table 3 and Table 4, respectively.

Step 3. The DHHFLTSs defined in Table 3 and Table 4 are aggregated using Equation 16, and mean HFLEs are calculated for each position and player using Equation 21 (Table 3, Table 4).

Step 4. The membership degrees of the difference of the HFLTEs from the average HFLTEs are calculated using Equation 3. Variance values are calculated over the difference between positions and players from the average HFLTE using Equation 19 (Table 5, Table 6).

Step 5. Correlation coefficient values reflecting the relationship between positions and players are defined using Equation 20 (Table 7).

Table 5. Membership degrees and variance values of positions

	Physical	Mental	Technical	Variance
Goal	0.556	0.667	0.611	0.0021
Defender	0.833	0.667	0.667	0.0062
Midfielder	0.556	0.806	0.833	0.0156
Forward	0.833	0.806	0.778	0.0005

Table 6. Membership degrees and variance values of players

	Physical	Mental	Technical	Variance
Burak	0.361	0.528	0.667	0.0156
Mehmet	0.889	0.806	0.750	0.0033
Servet	0.472	0.889	0.750	0.0300
Umut	1.000	0.722	0.833	0.0130

According to the results of Table 7 and Figure 2, which reflect the relations between positions and players, Servet is assigned to goal, Umut to defender, Burak to midfielder and Mehmet to forward. Umut is determined as the most unsuitable player for the goal position. Although Mehmet and Umut have equal similarity values for the defender, the most suitable person for the forward is determined as Mehmet and Umut is assigned to the defender position.

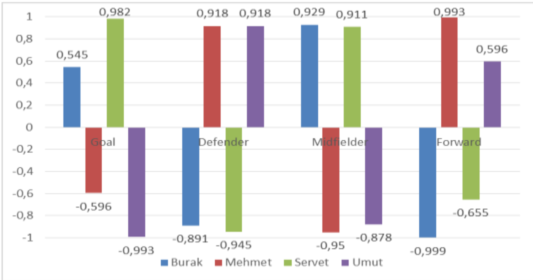

Figure 1. The Relationship between positions and players

While Burak is chosen as the most suitable person in the midfield, Mehmet is seen as the most unsuitable player for the midfield position. While Mehmet is assigned with the highest correlation value for the forward position, the most inappropriate player is determined as Burak.

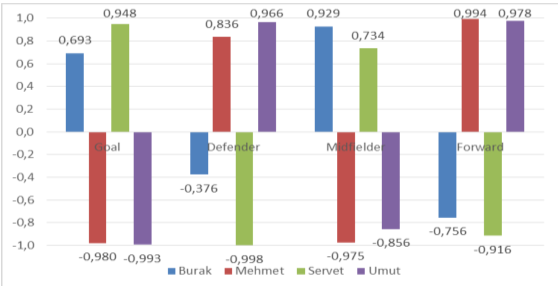

Figure 3. Position player relationship according to current method

The consistency and validity of the proposed method are revealed by comparing the proposed method with the current method (Figure 3). While Servet (0.948) is the most suitable player for the goal position, Umut (-0.993) and Mehmet (-0.980) are the most unsuitable players. Burak is the most suitable player for midfield (0.929) with

Table 7. Correlation coefficient matrix reflecting position and player relationship

	Goal	Defender	Midfielder	Forward	Position
Burak	0.545	-0.891	0.929	-0.999	Midfielder
Mehmet	-0.596	0.918	-0.950	0.993	Forward
Servet	0.982	-0.945	0.911	-0.655	Goal
Umut	-0.993	0.918	-0.878	0.596	Defender

While it is necessary to choose between Mehmet and Umut between the forward and the defender, Mehmet is chosen with the highest correlation value (0.994) with the forward position and Umut (0.966) is appointed as the most suitable player for the defender.

Comparative evaluations show that the new method, which proposes to continue with the fuzzy calculation method, is consistent with the current method. By continuing the process with fuzzy calculations, the efficiency of hesitancy evaluations in calculations is increased and the power of reflecting the evaluations of the experts to the result increases.

6. Conclusion

Linguistic terms are an important tool in reflecting the evaluations of experts more easily in complex decision making problems. This study deals with the correlation coefficient-based decision making method using DHHFLTSs, which are an important tool in reflecting complex linguistic assessments. In the current method, the direct correlation coefficient calculation over the membership degrees of fuzzy evaluations based on DHFLTs is seen as an important shortcoming.

The proposed method continues the calculation process of the correlation degree with hesitant linguistic evaluations, and hesitancy evaluations are included in the calculations. The proposed method deals with the original decision making problem as assigning the most suitable player to the positions in football. The existing and proposed new method are compared based on this decision-making problem and the consistency of the proposed method is revealed with the results.

Future studies may include incorporating HFLTs with different aggregation methods in correlation calculations based on DHHFLTS. Thus, hesitant expressions are transferred to evaluation processes more comprehensively. In addition, the proposed method can be applied to different and comprehensive decision making problems.

Article Information Form

Funding

The author(s) has no received any financial support for the research, authorship or publication of this study.

The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

References

[1] A. S. Yalcin, H. S. Kilic, “Green supplier selection via an integrated multi-attribute decision making approach”, Sakarya University Journal of Science, vol. 23, no 6, pp. 1066-1079, 2019.

[2] L. A. Zadeh, R. A. Aliev, Fuzzy logic theory and applications: part I and part II. World Scientific Publishing, 2018.

[3] X. Gou, H. Liao, Z. Xu, F. Herrera, “Double hierarchy hesitant fuzzy linguistic term set and MULTIMOORA method: A case of study to evaluate the

implementation status of haze controlling measures", Information Fusion, vol. 38, pp. 22-34, 2017.

[4] X. Gou, H. Liao, Z. Xu, F. Herrera, "Double hierarchy hesitant fuzzy linguistic term set and MULTIMOORA method: A case of study to evaluate the implementation status of haze controlling measures", Information Fusion, vol. 38, pp. 22-34, 2017.

[5] X. Gou, Z. Xu, H. Liao, F. Herrera, "Multiple criteria decision making based on distance and similarity measures under double hierarchy hesitant fuzzy linguistic environment", Computers & Industrial Engineering, vol. 126, pp. 516-530, 2018.

[6] X. Gou, Z. Xu, H. Liao, F. Herrera, "Multiple criteria decision making based on distance and similarity measures under double hierarchy hesitant fuzzy linguistic environment", Computers & Industrial Engineering, vol. 126, pp. 516-530, 2018.

[7] Z. Liu, X. Zhao, L. Li, X. Wang, D. Wang, "A novel multi-attribute decision making method based on the double hierarchy hesitant fuzzy linguistic generalized power aggregation operator", Information, vol. 10, no 11, p. 339, 2019.

[8] X. Gou, Z. Xu, "Managing noncooperative behaviors in large-scale group decision-making with linguistic preference orderings: The application in Internet venture capital", Information Fusion, vol. 69, pp. 142-155, 2021.

[9] X. Wang, X. Gou, Z. Xu, "Appeppment of traffic congestion with ORESTE method under double hierarchy hesitant fuzzy linguistic environment", Applied Soft Computing, vol. 86, p. 105864, 2020.

[10] E. Gumus, "A Case Study on the Relationship between Water Quality Parameters: Bursa", Sakarya University Journal of Science, vol. 26, no 5, pp. 867-878, 2022.

[11] A. G. Asuero, A. Sayago, A. González, "The correlation coefficient: An overview", Critical reviews in analytical chemistry, vol. 36, no 1, pp. 41-59, 2006.

[12] R. Zhang, X. Gou, Z. Xu, "A multi-attribute decision-making framework for Chinese medicine medical diagnosis with correlation measures under double hierarchy hesitant fuzzy linguistic environment", Computers & Industrial Engineering, vol. 156, p. 107243, 2021.

[13] B. Chaudhuri, A. Bhattacharya, "On correlation between two fuzzy sets", Fuzzy Sets and Nostems, vol. 118, no 3, pp. 447-456, 2001.

[14] VOL. Murthy, S. Pal, D. D. Majumder, "Correlation between two fuzzy membership functions", Fuzzy sets and nostems, vol. 17, no 1, pp. 23-38, 1985.

[15] H. Garg, K. Kumar, "A novel correlation coefficient of intuitionistic fuzzysets based on the connection number of set pair analysis and its application", Scientia Iranica, vol. 25, no 4, pp. 2373-2388, 2018.

[16] Z. Ren, Z. Xu, H. Wang, "Dual hesitant fuzzy VIKOR method for multi-criteria group decision making based on fuzzy measure and new comparison method", Information Sciences, vol. 388, pp. 1-16, 2017.

[17] J. Montserrat-Adell, Z. Xu, X. Gou, N. Agell, "Free double hierarchy hesitant fuzzy linguistic term sets: An application on ranking alternatives in GDM", Information Fusion, vol. 47, pp. 45-59, 2019.

[18] T. Gerstenkorn, J. Mańko, "Correlation of intuitionistic fuzzy sets", Fuzzy sets and nostems, vol. 44, no 1, pp. 39-43, 1991.

[19] A. Singh, "Modified expreppion to evaluate the correlation coefficient of dual hesitant fuzzy sets and its application to multi-attribute decision making", Fuzzy Nostems-Theory and Applications, 2020.

[20] R. Zhang, Z. Li, H. Liao, "Multiple-attribute decision-making method based on the correlation coefficient between dual hesitant fuzzy linguistic term sets", Knowledge-Based Nostems, vol. 159, pp. 186-192, 2018.

[21] J. Lago-Ballesteros, VOL. Lago-Peñas, "Performance in team sports: Identifying the keys to succepp in soccer", Journal of Human kinetics, vol. 25, no 1, pp. 85-91, 2010.

[22] N. Razali, A. Mustapha, F. A. Yatim, R. Ab Aziz, "Predicting player position for talent identification in appociation football", IOP Conference Series: Materials Science and Engineering, 2017, vol. 226, no 1, s. 012087.

[23] Z. Ayağ, F. Samanlioglu, "A hesitant fuzzy linguistic terms set-based AHP-TOPSIS approach to evaluate ERP software packages", International Journal of Intelligent Computing and Cybernetics, 2020.

[24] X. Gou, Z. Xu, "Double hierarchy linguistic term set and its extensions", Double Hierarchy Linguistic Term Set and Its Extensions, Springer, 2021, pp. 1-21.

[25] M. Bhatia, H.D. Arora, N. Anjali "Some New Correlation Coefficient Measures Based on Fermatean Fuzzy Sets using Decision Making Approach in Pattern Analysis and Supplier Selection", International Journal of Mathematical, 8 (2), 2023.

[26] D. Li, W. Zeng, J. Li, "New distance and similarity measures on hesitant fuzzy sets and their applications in multiple criteria decision making", Engineering Applications of Artificial Intelligence, vol. 40, pp. 11-16, 2015.

[27] X. Gou, Z. Xu, W. Zhou, "Interval consistency repairing method for double hierarchy hesitant fuzzy linguistic preference relation and application in the diagnosis of lung cancer", Economic Research-Ekonomska Istraživanja, vol. 34, no 1, pp. 1-20, 2021.

[28] S. Buyrukoğlu, S. Savaş, "Stacked-Based Ensemble Machine Learning Model for Positioning Footballer", Arabian Journal for Science and Engineering, pp. 1-13, 2022.

[29] D. Barron, G. Ball, M. Robins, VOL. Sunderland, "Identifying playing talent in profeppional football using artificial neural networks", Journal of Sports Sciences, vol. 38, no 11-12, pp. 1211-1220, 2020.

[30] VOL. T. Woods, J. P. Veale, N. Collier, S. Robertson, "The use of player physical and technical skill match activity profiles to predict position in the Australian Football League draft", Journal of sports sciences, vol. 35, no 4, pp. 325-330, 2017.