Sport Management Review 16 (2013) 97–110

Contents lists available at SciVerse ScienceDirect

Sport Management Review

journal homepage: www.elsevier.com/locate/smr

A fuzzy inference system with application to player selection and team formation in multi-player sports

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ARTICLE INFO

Article history:
Received 24 April 2012
Received in revised form 5 June 2012
Accepted 5 June 2012

Keywords:
Fuzzy inference system
Fuzzy sets and logic
Player selection
Team formation
Soccer

ABSTRACT

The success or failure of any team lies in the skills and abilities of the players that comprise the team. The process of player selection and team formation in multi-player sports is a complex multi-criteria problem where the ultimate success is determined by how the collection of individual players forms an effective team. In general, the selection of soccer players and formation of a team are judgments made by the coaches on the basis of the best available information. Very few structured and analytical models have been developed to support coaches in this effort. We propose a two-phase framework for player selection and team formation in soccer. The first phase evaluates the alternative players with a fuzzy ranking method and selects the top performers for inclusion in the team. The second phase evaluates the alternative combinations of the selected players with a Fuzzy Inference System (FIS) and selects the best combinations for team formation. A case study is used to illustrate the performance of the proposed approach.

1. Introduction

The process of player selection and team formation in multi-player sports is a complex multi-criteria problem with conflicting objectives. Selection of players in a team is always a difficult decision making task with many dimensions. Coaches are required to consider a large number of qualitative and quantitative attributes in the player selection process. These attributes may include the player's individual skills and performance statistics, combination of players, physical fitness, psychological factors, and injuries among others (Arnason et al., 2004). Some coaches may also use importance weights to determine the impact of each attribute. Importance weights are useful to coaches since they indicate how the impact of a particular attribute relates to the probability of a successful outcome.

Soccer (more commonly known as football in many regions) is a team sport that is popular in almost every country in the world. The player selection process for professional soccer teams is crucial in the quest for winning. So much so that a wrong selection can cost a soccer team the championship and even millions of dollars if the player turns out not living up to the team's expectations. Traditionally, professional soccer teams use a variety of sports psychology assessments for evaluating players. There is no doubt that these assessments are of great benefit and are extremely useful when trying to form a winning soccer team. However, this is just one part of the big puzzle when trying to assess a player's suitability for a team. The ability

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1441-3523/$ – see front matter
http://dx.doi.org/10.1016/j.smr.2012.06.002

to select suitable players and arrange an effective team formation is indispensable for reaching the top for team sports (Boon & Sierksma, 2003).

Katzenbach and Smith (1993) defined a team as a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable. The main goal of team building is teamwork, which is the vehicle for integrating information, technology, competence and resources based on human interactions (Kinlaw, 1991). A variety of approaches for the selection of team members have been proposed in the literature. Most of these studies have focused on the use of teams in business and industry. The business and industry's adoption of a teamwork methodology in the pursuit of cost effectiveness and greater innovation has spawned significant research (Chen, Cheng, & Chuang, 2008; English, Griffith, & Steelman, 2004; Kirkman, Rosen, Tesluk, & Gibson, 2004; Mannix & Neale, 2005).

The conceptual work of several scholars has highlighted five key elements for team-building: clear goals with measurable outcomes, clinical and administrative systems, division of labor, training, and communication (Baldwin, 1994; Cohen & Bailey, 1997; Fried, Topping, & Rundall, 2000).

Askin and Sodhi (1994) have presented a novel method for organizing teams in concurrent engineering. They developed five different criteria for team formation and discussed team training, leadership, and computer support issues. Zakarian and Kusiak (1999) proposed an analytical model for the selection of multi-functional teams. They used the analytic hierarchy process and the quality function deployment method to prioritize "team membership" based on customer requirements and product specifications. Braha (2002) has proposed a team-building approach based on task partitioning by specifying task dependencies and partitioning the tasks among a number of teams. Chen and Lin (2004) proposed a team member model for the formation of a multi-functional team in concurrent engineering. They used the analytic hierarchy process and Myers–Briggs type indicators to model team member characteristics. In the software development field, Gronau, Fröming, Schmid, and Rüssbüldt (2006) developed an algorithm to propose a team composition for a specific task by analyzing the knowledge and skills of the employees. In the project management field, Durmusoglu and Kulak (2008) proposed a team building process using axiomatic design principles. They proposed to establish teams by identifying the needed skills and preparing a skill development procedure to ensure maximum utilization of team members' talents. Feng, Jiang, Fan, and Fu (2010) proposed a member selection method in cross functional teams where both the individual performance of the candidates and the collaborative performance between candidates were considered.

Fuzzy set theory has also been used in the team member selection and team formation research. Liang and Wang (1992) proposed integrating fuzzy logic into weighted complete bipartite graphs and developing a polynomial time algorithm for solving personnel placement. Yaakob and Kawata (1999) used triangular fuzzy numbers to evaluate the workers' skills and measure their suitability in work teams. DeKorvin, Shipley, and Kleyle (2002) developed a model for the selection of personnel in multiple phase projects, which took into account the match between the skills possessed by each individual, the skills needed for each phase, and flexible budget considerations. They used the fuzzy construct of compatibility to measure the fit of a person's skill set to the goal set for each project phase in fuzzy environment. Dereli, Baykasoglu, and Das (2007) used simulated annealing and proposed a fuzzy mathematical programming model for the formation of quality audit teams. Shipley and Johnson (2009) proposed a fuzzy set-based model for selecting project membership to achieve cognitive style goals.

The above studies demonstrate the importance of team member selection in a wide variety of applications. In spite of the importance of member selection and team formation research in business and industry, this subject has not been widely researched in the sport science literature. The current literature on player selection and team formation in multi-player sports is very limited and scattered. Boon and Sierksma (2003) formulated a linear optimization model to headhunt or scout a new team in soccer and volleyball by combining the qualities of the candidates and players with the functional requirements. Merigó and Gil-Lafuente (2011) analyzed the use of the ordered weighted averaging (OWA) operator in the selection of human resources in sport management. They used the Hamming distance, the adequacy coefficient and the index of maximum and minimum level to parameterize these decision-making techniques and select of a football player for a team. Ahmed, Deb, and Jindal (2011) considered the overall batting and bowling strength of a cricket team and proposed a constrained multi-objective optimization model for selection of the players on the team.

Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling uncertain industrial, human and natural systems. They are facilitators in decision making by means of approximate reasoning and linguistic terms. Their role is significant when applied to complex phenomena not easily described by traditional mathematics. Moreover, users often feel more comfortable using linguistic terms instead of precisely specified numerical values. Sport management often involves decision making in the absence of precise and complete information. Fuzzy sets and logic can be effectively used in sport management applications such as sport operations, sport economics, sport marketing, sport human resources, and sport facility management.

In this paper, we propose a Fuzzy Inference System (FIS) for player selection and team formation in soccer. Fuzzy sets are used to transform the linguistic variables used for assessing the players' performance on multiple attributes into triangular numbers. The linguistic variables are used to deal with the difficulty in expressing players' skill levels and performance ratings with discrete values. Fuzzy numbers are very useful in promoting the representation and information processing under fuzzy environment (Dubois, 1978). The linguistic variables are also used to assess the performance of each candidate player in different positions.

A FIS is a non-linear system that employs fuzzy IF–THEN rules to model the qualitative aspects of human knowledge without employing precise quantitative analyses. The most popular fuzzy logic modeling techniques can be classified into three types: the linguistic models (Mamdani-type) (Mamdani & Assilian, 1975), the relational equation models, and the Takagi–Sugeno–Kang models (Sugeno, 1985). In linguistic models, both the antecedent and the consequence are fuzzy sets while in the Takagi–Sugeno–Kang models the antecedent consists of fuzzy sets but the consequence is comprised of linear equations. Fuzzy relational equation models aim at building the fuzzy relation matrices according to the input–output process data. The FIS proposed in this study is intended to evaluate alternative player arrangements.

The remainder of this paper is organized as follows. In Section 2, we provide an overview of fuzzy set theory. In Section 3, we present the details of the proposed approach. In Section 4, we present a case study to illustrate the effectiveness and applicability of the proposed approach. Finally, in Section 5, we present our conclusions and future research directions.

2. Fuzzy set theory

Many real-world applications cannot be described and handled by classical set theory. Fuzzy set theory, proposed by Zadeh (1965) is a powerful technique for dealing with the sources of imprecision and uncertainty that are non-classical in nature. In the absence of complete and precise information, fuzzy sets and logic are widely used to model uncertain systems (Saghafian & Hejazi, 2006; Soltani & Haji, 2007; Zadeh, 1965).

2.1. Fuzzy logic and fuzzy operations

A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership $\mu_{\tilde{A}}(x)$ which associates with each element x in X a real number in the interval [0,1]. The function value is termed the grade of membership of x in $\tilde{A}$ (defined by Zadeh, 1965). A fuzzy set $\tilde{A}$ in X is a set of ordered pairs:

$$\tilde{A} = \{[x, \mu_{\tilde{A}}(x) | x \in X]\} \tag{1}$$

where the membership value $\mu_{\tilde{A}}(x)$ can take values between [0,1]. Complete non-membership is represented by 0, and complete membership as 1. The values between 0 and 1 represent intermediate degrees of membership. Fuzzy numbers are the special classes of fuzzy quantities. A fuzzy number is a fuzzy quantity $\tilde{A}$ that represents a generalization of a real number. There are different classes of fuzzy numbers, but triangular and trapezoidal fuzzy numbers are the most commonly used classes of fuzzy numbers in real-world problems. A triangular fuzzy number is defined by three real numbers, namely, the triplet (a, b, c), where $a < b < c$. The possibility degree is measured by the membership function $\mu(x)$, where the x argument refers to events. In the triangular fuzzy number, we have $\mu(a) = \mu(c) = 0$ while $\mu(b) = 1$ (Eq. (2) and Fig. 1). The membership function has the following form:

$$\mu_{\tilde{A}}(x) = \begin{cases} 1 - \dfrac{(a-x)}{\alpha} & a - \alpha \le x \le a \\ 1 - \dfrac{(a-x)}{\beta} & a \le x \le a + \beta \\ 0 \quad \text{otherwise} \end{cases} \tag{2}$$

A linguistic variable is a variable whose values are expressed in linguistic terms (Zhang, 1986) and differs from a numerical variable in that its values are not numbers, but words or sentences in natural or artificial language (Zadeh, 1975). The concept of a linguistic variable is very useful in describing situations that are too complex or not well-defined in conventional quantitative expressions.

The algebraic operations on fuzzy numbers can be defined by using the extension principle. In this paper, some algebraic operations developed by Dubois (1978) were used. Assume that there are two linguistic variables expressed as fuzzy numbers $\tilde{A}_1$ and $\tilde{A}_2$, where $x_1 = (a_1, b_1, c_1)$ and $x_2 = (a_2, b_2, c_2)$. According to x_1 and x_2, the most widely used basic fuzzy operations are defined in Table 1.

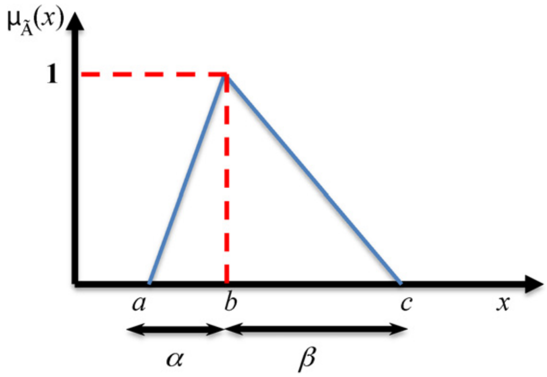

Fig. 1. The triangular fuzzy number.

Table 1
The basic fuzzy operations.

Opposite	$-(a_1, b_1, c_1) = (-a_1, -b_1, -c_1)$
Reverse	$(a_1, b_1, c_1)^{-1} = \left(\frac{1}{c_1}, \frac{1}{b_1}, \frac{1}{a_1}\right)$
Addition	$(a_1, b_1, c_1) \oplus (a_2, b_2, c_2) = (a_1 + a_2, b_1 + b_2, c_1 + c_2)$
Subtraction	$(a_1, b_1, c_1) - (a_2, b_2, c_2) = (a_1 - a_2, b_1 - b_2, c_1 - c_2)$
Multiplication by scalar	$k \otimes (a_1, b_1, c_1) = (ka_1, kb_1, kc_1)$
Multiplication by fuzzy	
For $x_1 > 0, x_2 > 0$	$(a_1, b_1, c_1) \otimes (a_2, b_2, c_2) = (a_1a_2, b_1b_2, c_1c_2)$
For $x_1 < 0, x_2 > 0$	$(a_1, b_1, c_1) \otimes (a_2, b_2, c_2) = (c_1a_2, b_1b_2, a_1c_2)$
For $x_1 < 0, x_2 < 0$	$(a_1, b_1, c_1) \otimes (a_2, b_2, c_2) = (c_1c_2, b_1b_2, a_1a_2)$
Division by fuzzy	
For $x_1 > 0, x_2 > 0$	$(a_1, b_1, c_1)/(a_2, b_2, c_2) = \left(\frac{a_1}{a_2}, \frac{b_1}{b_2}, \frac{c_1}{c_2}\right)$
For $x_1 < 0, x_2 > 0$	$(a_1, b_1, c_1)/(a_2, b_2, c_2) = \left(\frac{c_1}{c_2}, \frac{b_1}{b_2}, \frac{a_1}{a_2}\right)$
For $x_1 < 0, x_2 < 0$	$(a_1, b_1, c_1)/(a_2, b_2, c_2) = \left(\frac{c_1}{a_2}, \frac{b_1}{b_2}, \frac{a_1}{c_2}\right)$

2.2. Fuzzy IF–THEN rules and FIS

The fuzzy IF–THEN rules or fuzzy conditional statements are expressions in the form of IF *A* THEN *B*, where *A* and *B* are labels of fuzzy sets (Zadeh, 1965) characterized by appropriate membership functions. Due to their concise form, fuzzy IF–THEN rules are often employed to capture the imprecise modes of reasoning that play an essential role in the human ability to make decisions in uncertain and imprecise environments. If a given fuzzy rule has multiple antecedents, the fuzzy operator (AND or OR) is used to obtain a single number that represents the result of the antecedent evaluation (Eqs. (3) and (4)). This number (the truth value) is then applied to the consequent membership function. To evaluate the disjunction of the rule antecedents, an OR fuzzy operation is used. Typically, using the fuzzy operation union:

$$\mu_{A\cup B}(X) = \max[\mu_A(X), \mu_B(X)] \tag{3}$$

Similarly, in order to evaluate the conjunction of the rule antecedents, an AND fuzzy operation is applied to the intersection:

$$\mu_{A\cap B}(X) = \min[\mu_A(X), \mu_B(X)] \tag{4}$$

Fuzzy IF–THEN rules form a core part of the FIS. Fuzzy inference employing fuzzy IF–THEN rules can easily model the qualitative aspects of linguistic human knowledge and reasoning processes without precise quantitative analyses (Ho, Zhang, & Xu, 2001).

The FIS provides a computational framework for manipulating and reasoning the imprecise expressions in an environment. The main goal of an FIS is to model human decision-making within the conceptual framework of fuzzy logic and approximate reasoning (Horikawa, Furuhashi, & Uchikawa, 1992). The FISs have been successfully applied in several fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Fuzzy inference is the real process of mapping from a given set of input variables to an output relied upon a set of fuzzy rules. In general, a FIS consists of four modules as shown in Fig. 2 (Huang & Chiu, 2009).

The fuzzification module transforms the system inputs, which are crisp numbers, into fuzzy sets by applying a fuzzification function. The inference engine simulates the human reasoning process by making fuzzy inferences on the inputs through a set of rules. These rules are expressed with an IF–THEN format (If *x* is *A*, Then *y* is *B*). The membership degrees for each confirmed rule in the rule evaluation process (rule firing) are simplified to one membership degree using fuzzy implication. There are different ways to define an implication (Mamdani, 1977; Mizumoto & Zimmermann, 1982; Zadeh, 1971). The outputs of the rule evaluation are unified using an aggregation process that combines the membership functions into a single membership function. The defuzzification module transforms the fuzzy set obtained by the inference engine into a crisp value. Many different defuzzification methods have been proposed (Ross, 1995), such as centroid of area, bisector of area, mean of maxima, maximum criterion (Lee, 1990).

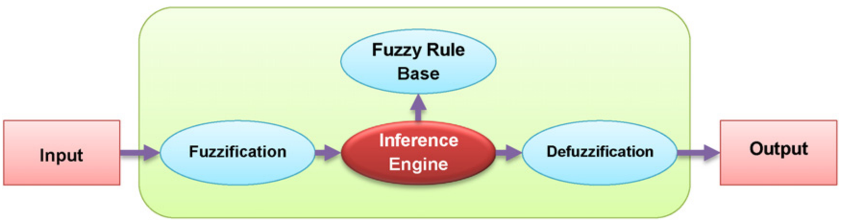

Fig. 2. The fuzzy inference system.

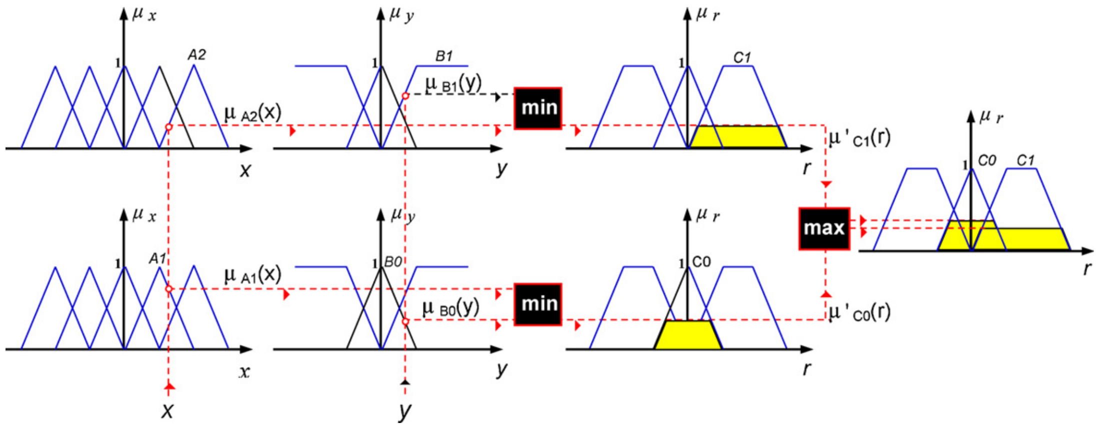

Fig. 3. The Mamdani's fuzzy inference method.

There are two types of FISs that can be implemented in the Fuzzy Logic Toolbox: Mamdani-type (Mamdani & Assilian, 1975) and Sugeno-type (Takagi & Sugeno, 1985). These two FISs vary in the way outputs are determined. The first type is used in this paper. The Mamdani's method is used most commonly in the real-world applications due to its simplicity in structuring the 'min–max' operations. In summary, Fig. 3 shows a two input Mamdani FIS with two rules. It fuzzifies the two inputs by finding the intersection of the crisp input value with the input membership function. It uses the minimum operator to compute the fuzzy "and" for combining the two fuzzified inputs to obtain a rule strength. It clips the output membership function at the rule strength. Finally, it uses the maximum operator to compute the fuzzy "or" for combining the outputs of the two rules.

3. The proposed approach

As in all team sports, soccer players must specialize at various positions and understand how to interact with their teammates in other positions in order to effectively compete in the game. This is especially true for soccer where players need the structure a system of play known as formation to be able to properly perform. The general terms used for different positions in soccer are: goalkeeper, defenders, midfielders, and forwards. In general, each team has 20 players (without considering the three goalkeepers) and 10 are chosen by the coaches as the starting lineup to participate in the event when the game begins. The number of players in each of the three positions is based on the team formation selected for the game.

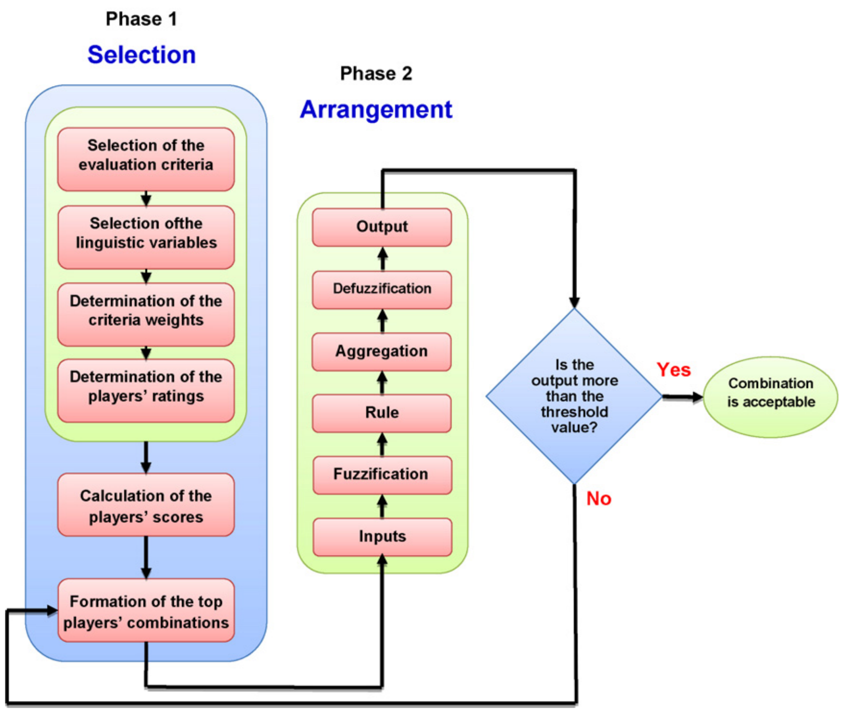

Fig. 4. A graphical representation of the proposed framework.

We present a two-phase approach depicted in Fig. 4 for team selection and arrangement. In the selection phase, we use a fuzzy ranking method to evaluate the alternative players. The fuzzy ranking method proposed by Yaakob and Kawata (1999) is employed in this phase to choose the team members. In the arrangement phase, the FIS is used to evaluate various combinations among the team members in each position.

3.1. Phase 1: Selection

Evaluating soccer players is a challenging process, particularly when the criteria used for evaluation are based on skill, vision, and tactical insight. In this phase, we identify a set of evaluation criteria such as ability to control the ball, dribbling skills, ability to recover the ball, ability to create space to receive a pass, score goals. Coaches generally evaluate each player based on their preferred evaluation criteria. We use linguistic variables for the weight of the evaluation criteria and the player ratings for each position. After compiling and synthesizing these weights and ratings, Eq. (5) is used to calculate a total score for each player in different positions:

$$E_{eval}(PO, i) = \frac{1}{k}\sum_{t=1}^{k} e(i, PO, C_t) \otimes W(PO, C_t) \tag{5}$$

where $E_{eval}(PO, i)$ is the total score for each player for a given position, $e(i, PO, C_t)$ is the performance rating of a player on an evaluation criterion for a position, and $W(PO, C_t)$ is the importance weight of an evaluation criterion for a position. The center value of these triangular membership functions presents the maximal grade of the membership and the most possible value for a player's suitability (Yaakob & Kawata, 1999).

In the final step, the top three combinations for the defenders, midfielders and forwards are identified. The reason for selecting three combinations for each position is to provide the coaches with the ability to discard unacceptable combinations.

3.2. Phase 2: Arrangement

In this phase we use FIS to arrange the selected players for each position. The inputs to the FIS model are provided by the coaches based on the arrangement factors (e.g. the number of times players have played together, the number of times players passed the ball to each other in a game, etc.). The output of the FIS is the percentage of arrangement (POA) for the top player combination in each position. In order to convert the inputs into outputs, FIS requires a fuzzification of the inputs, an evaluation of the associated rules, an aggregation of the associated rules, and a posterior defuzzificaton of the aggregation result. If the POA is more than the threshold value, the proposed combination is considered acceptable; otherwise, the combination with the next highest score should be substituted and the POA should be recalculated.

4. Illustrative case study

The proposed approach is illustrated with the real data obtained from the Parsan[1] Soccer Club (PSC), a professional soccer team based in Tehran, Iran. Parsan was founded in 1968 and has been in the first division of Iranian soccer since 1974. Without considering three goalkeepers, the team is comprised of 20 players including seven defenders, eight midfielders, and five forwards. Three coaches including the head coach, the offensive coach, and the defensive coach agreed to use the method proposed in this study to form a team for the league championship game. The coaches had selected a 4–4–2 formation for the upcoming game. This is the most popular and balanced formation in soccer today. The formation consists of 4 defenders, 4 midfielders and two forwards as shown in Fig. 5.

The team formation process was divided into two phases: the selection phase and the arrangement phase.

4.1. Phase 1: Selection

In this phase, the three coaches considered 18 evaluation criteria presented in Table 2. These criteria had been routinely used by the coaches for team formation at the PSC in the past.

The players' assessment of the 18 evaluation criteria were expressed with the following linguistic variables proposed by Karsak (2000): "Poor (P)", "Fair (F)", "Good (G)" and "Very Good (VG)". Fig. 6 presents the membership function of the linguistic variables used for performance assessment. The importance weight of the criteria were also expressed with linguistic variables with the following values: "Not important (NI)", "Not so important (NS)", "Normal (N)", "Important (I)" and "Very important (VI)". Fig. 7 shows the membership function of the linguistic variables used for weight assessment.

In the next step, the three coaches collectively assigned the importance weights given in Table 3 for each of the 18 criteria for the three different positions. They also assigned the performance ratings in the form of linguistic variables given in Table 4 for the 20 players based on their previous performance prior to the playoff season.

[1] The name changed to protect the anonymity of the football team which participated in this study.

Fig. 5. A graphical display of the 4–4–2 formation.

Table 2
The evaluation criteria.

Criterion number	Criteria description
C1	Heading, jumping
C2	Shoot
C3	Short passing
C4	Crossing
C5	Ball control
C6	Dribbling
C7	Finishing (composure)
C8	Speed
C9	Creativity
C10	Create goal scoring position
C11	Tackling
C12	Both feet
C13	Great stamina
C14	Height
C15	Providing through (long) pass
C16	Technical ability
C17	Create attacking opportunities
C18	Read the game

Data collected in Tables 3 and 4 provided the basis for calculating and overall score of the players for three different positions given in Table 5. For example, the score for player 1 is calculated as follows:

$$\begin{aligned} G \times VI + F \times NS + G \times VI + \cdots + G \times NS + F \times I + G \times I &= (0.6, 0.8, 0.9) \times (2.5, 3, 3.5) + (0.3, 0.5, 0.7) \times (1, 1.5, 2) \\ &\quad + (0.6, 0.8, 0.9) \times (2.5, 3, 3.5) + \cdots + (0.6, 0.8, 0.9) \times (1, 1.5, 2) \\ &\quad + (0.3, 0.5, 0.7) \times (2, 2.5, 3) + (0.6, 0.8, 0.9) \times (2, 2.5, 3) \\ &= (12.6, 25.45, 37.55) \end{aligned}$$

Table 6 shows the overall score and ranking of each player for each position based on the middle value of the triangular numbers presented in Table 5.

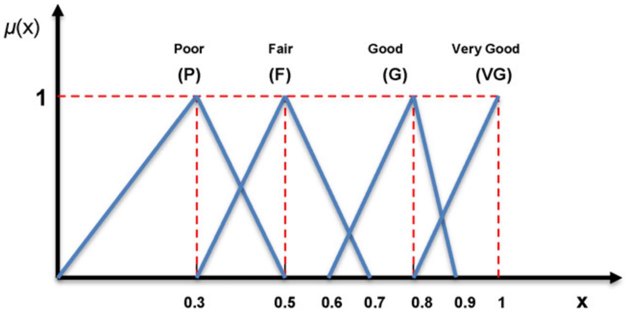

Fig. 6. The membership function used for the performance scores.

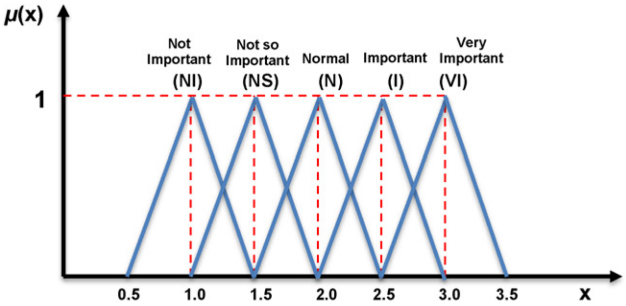

Fig. 7. The membership function used for the importance weights.

In the final step, the three top quadruple combinations of the defenders and midfielders and the three top binary combinations of the forwards were formed and then ranked by their average score. For example, the average score for combination (5, 2, 7, 1), which was formed by four top players for defender position, was obtained as follows:

$$\frac{27.75 + 26.8 + 25.9 + 25.45}{4} = 26.47$$

Table 7 shows the overall ranking of the top three 4–4–2 combinations. According to this table, combinations (5, 2, 7, 1), (5, 2, 7, 6), and (5, 2, 7, 4) were the top three combinations for the defenders position; combinations (12, 14, 13, 8), (12, 14, 13, 9), and (12, 14, 13, 15) were the top three combinations for the midfielders position; and combinations (18, 20), (18, 17), and (18, 19) were the top three combinations for the forwards position.

Table 3
The criteria weights.

Criterion number	Defender	Midfielder	Forward
C1	VI	N	VI
C2	NS	I	VI
C3	VI	VI	I
C4	NS	I	I
C5	I	VI	VI
C6	NS	VI	I
C7	NS	N	VI
C8	N	I	VI
C9	NS	VI	I
C10	NS	I	VI
C11	VI	I	NS
C12	NS	NS	I
C13	N	VI	I
C14	I	NS	VI
C15	NS	VI	I
C16	NS	I	VI
C17	I	VI	I
C18	I	VI	I

Table 4
The performance rating of each player with respect to different criteria.

Criterion number	Defender							Midfielder								Forward				
	Player number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
C1	G	G	VG	F	G	F	VG	G	G	F	G	F	P	VG	VG	G	G	VG	G	VG
C2	F	VG	G	P	F	G	G	F	G	G	VG	F	G	VG	G	VG	VG	G	G	G
C3	G	G	VG	G	G	F	G	G	VG	VG	G	VG	G	F	G	G	VG	G	G	G
C4	G	G	F	P	G	VG	F	G	G	G	F	G	VG	P	G	F	G	VG	G	G
C5	G	F	F	G	G	VG	G	G	VG	G	VG	G	F	G	VG	G	VG	G	VG	VG
C6	F	G	F	G	G	F	P	G	G	F	VG	G	G	VG	G	VG	F	VG	G	G
C7	F	F	G	P	F	G	G	G	F	G	VG	G	G	F	VG	G	G	VG	VG	G
C8	G	F	P	VG	G	G	G	VG	G	G	F	G	VG	G	VG	G	VG	G	G	VG
C9	F	G	F	F	G	P	G	G	VG	G	G	VG	G	VG	F	G	VG	G	G	VG
C10	F	G	P	F	P	F	F	G	G	G	F	G	VG	VG	G	VG	G	G	G	VG
C11	G	G	VG	VG	G	VG	G	G	G	F	F	G	VG	G	F	G	F	G	G	G
C12	P	G	P	F	G	F	P	F	F	F	G	G	F	G	F	P	F	VG	G	P
C13	G	G	F	G	VG	VG	G	G	G	VG	G	G	F	G	F	G	VG	VG	G	G
C14	G	G	F	VG	G	VG	G	G	F	F	G	G	G	G	VG	G	G	VG	F	VG
C15	G	G	G	F	G	G	F	F	G	F	VG	G	VG	G	G	VG	VG	G	G	G
C16	G	P	F	P	G	F	G	G	F	G	VG	G	VG	G	VG	G	G	VG	G	G
C17	F	G	F	P	G	F	F	G	VG	G	F	G	G	VG	VG	G	VG	G	G	G
C18	G	G	F	G	G	F	G	VG	F	G	F	G	VG	G	F	G	G	F	G	G

Table 5
The overall score of each player in three positions.

Position	Player number	Overall score
Defenders	1	(12.6, 25.45, 37.55)
	2	(13.85, 26.8, 38.85)
	3	(11.55, 22.2, 34.9)
	4	(10.75, 23, 35.15)
	5	(14.2, 27.75, 39.6)
	6	(12.4, 24.5, 37.35)
	7	(13.1, 25.9, 37.9)
Midfielders	8	(20.25, 35.25, 48.45)
	9	(20.9, 34.85, 48.3)
	10	(19.15, 33.35, 46.9)
	11	(19.5, 33.6, 47.6)
	12	(21.25, 36.05, 49.1)
	13	(21.9, 35.4, 48.9)
	14	(21.3, 35.65, 49)
	15	(20.05, 34.55, 48.4)
Forwards	16	(23.4, 37.5, 50.8)
	17	(25.4, 38.6, 52.25)
	18	(26.4, 39.85, 53.3)
	19	(23.65, 38.1, 51.3)
	20	(25.1, 38.9, 52.15)

4.2. Phase 2: Arrangement

This phase is intended to determine the best arrangement for the 4–4–2 formation. Let us consider the three defenders' combinations as an example to illustrate the procedure for identifying the best defenders combination. Based on the result from the previous phase, the top defensive combination was (5, 2, 7, 1) whose arrangement was calculated using the FIS. The coaches identified (x, y) as the two input factors influencing team arrangement:

- Factor x was the number of players' teammate relations (NOTR) in one (or both) of the two last games. The simultaneous presence of two players in one team was one teammate relation. Maximum value of NOTR is shown in Eq. (6).

$$\frac{n(n-1)}{2} \tag{6}$$

where n is the number of players in a specific position. In this case, the number of defenders was 4. Therefore, the maximum NOTR value was 6 for the proposed team. A schematic view of the NOTR ($x = 4$) is represented in Fig. 8. The line between points 2 and 7 in this figure shows that these players played in one (or both) of the last two games together.

Table 6
The overall score and ranking of each player.

Position	Player number	Overall score	Ranking
Defenders	5	27.75	1
	2	26.8	2
	7	25.9	3
	1	25.45	4
	6	24.5	5
	4	23	6
	3	22.2	7
Midfielders	12	36.05	1
	14	35.65	2
	13	35.4	3
	8	35.25	4
	9	34.85	5
	15	34.55	6
	11	33.6	7
	10	33.35	8
Forwards	18	39.85	1
	20	38.9	2
	17	38.6	3
	19	38.1	4
	16	37.5	5

Table 7
The overall ranking of the top three 4–4–2 combinations.

Position	Player combinations	Average rating	Ranking
Defenders	(5, 2, 7, 1)	26.47	1
	(5, 2, 7, 6)	26.23	2
	(5, 2, 7, 4)	25.86	3
Midfielders	(12, 14, 13, 8)	35.58	1
	(12, 14, 13, 9)	35.48	2
	(12, 14, 13, 15)	35.41	3
Forwards	(18, 20)	39.37	1
	(18, 17)	39.22	2
	(18, 19)	38.97	3

- Factor y is the average number of players (ANOP) who played together in the last 10 games. Table 8 shows the number of defenders out of four who played together in each of the last 10 games. The ANOP was calculated as follows:

$$y = \frac{(2 + 2 + 4 + \cdots + 3)}{10} = 2.9$$

Next, we converted the two inputs into the POAs for the top combinations for each position. A series of fuzzification, rule evaluation, aggregation and defuzzification procedures were used to accomplish these tasks. These procedures depicted in Fig. 9 are described next.

(i) *Fuzzification*: In this procedure, the crisp values were transformed into fuzzy values according to their respective membership functions. The membership function for the inputs x and y are shown in Fig. 9a and b, respectively. The membership degree for input ($x = 4$) was 0.5 in the M and H areas and the membership degree for input ($y = 2.9$) was 0.6 in the M and 0.4 in the H areas.
(ii) *Rule evaluation*: The results from the previous procedure showed that inputs x (ANOP) and y (NOTR) are positioned in the M and H areas. The combination of these four areas consisted of four rules shown in Fig. 9c. The membership degrees of

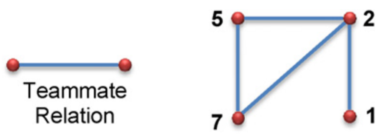

Fig. 8. The schematic view of the NOTR.

Table 8
The number of defenders who played simultaneously.

Match number	Number of defenders played together
1	2
2	2
3	4
4	3
5	2
6	3
7	3
8	4
9	3
10	3

the output function (Z) in the mentioned areas of the rule-based table were calculated according to Eqs. (7)–(10):

$$\mu_{MO}(Z) = \mu_M(4) \wedge \mu_M(2.9) = \min(0.6, 0.5) = 0.5 \quad (7)$$

$$\mu_H(Z) = \mu_M(4) \wedge \mu_H(2.9) = \min(0.5, 0.4) = 0.5 \quad (8)$$

$$\mu_H(Z) = \mu_H(4) \wedge \mu_M(2.9) = \min(0.5, 0.6) = 0.5 \quad (9)$$

$$\mu_E(Z) = \mu_H(4) \wedge \mu_H(2.9) = \min(0.5, 0.4) = 0.4 \quad (10)$$

(iii) *Aggregation*: The membership degrees from the rule evaluation procedure were graphically represented by a line in each area of the output function where more than one membership degree was obtained. The maximum value for these degrees was selected according to Eq. (11) and the output function areas were aggregated accordingly. The results of the aggregation procedure represent an area which contains the fuzzy solution to the problem. This area is represented with heavy red lines in Fig. 9d.

$$\mu_{agg} = \max\{\min(0.5, MO), \min(0.5, H), \min(0.4, E)\} \quad (11)$$

(iv) *Defuzzification*: In this procedure, the Mamdani's inference system method (Mamdani & Assilian, 1975) was used to convert the fuzzy outputs into crisp output values through a defuzzification process. We used the Centroid method, one of the most popular defuzzification techniques, to transform the fuzzy values into crisp values as suggested in the Mamdani's inference system method (Ross, 1995). The crisp values of the outputs were obtained according to Eq. (12) in Fig. 9, where $\int$ denotes an algebraic integration.

Next, Delphi method was used to select a threshold value for the POAs in each position. The Delphi method was developed at the RAND Corporation to obtain the most reliable consensus of opinion from a group of knowledgeable individuals about an issue not subject to objective solution (Dalkey & Helmer, 1963). It is a structured group interaction that proceeds through multiple rounds of opinion collection and anonymous feedback. Although Delphi dates back to early 1950s, the most recognized description of the method was offered by Linstone and Turoff (1975). Fischer (1978), Schmidt (1997), Okoli and Pawloski (2004), and Keeney, Hasson, and McKenna (2006) also provide excellent reviews.

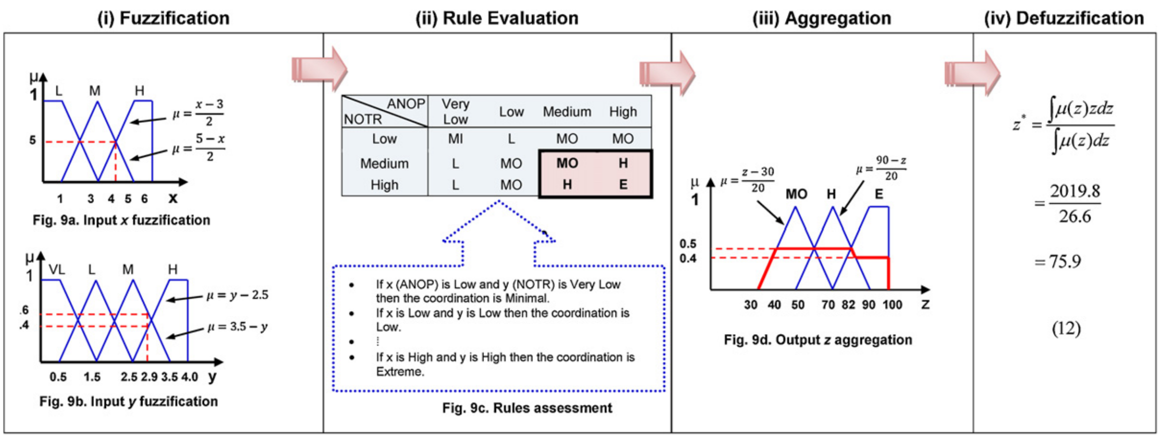

Fig. 9. The fuzzy rule-based calculation. (For interpretation of the references to color in the text, the reader is referred to the web version of the article.)

Table 9
The final 4–4–2 team formation.

Position	Player combinations
Defenders	(5, 2, 7, 1)
Midfielders	(12, 14, 13, 8)
Forwards	(18, 20)

Fig. 10. The final 4–4–2 team formation.

Each round in Delphi involves a written survey of the participants followed by statistical feedback to them for each survey question. After seeing the results from the previous round, the participants are asked to reconsider their opinions. Generally, there is a convergence of opinions after three or four rounds, and a stabilized group opinion emerges. This group opinion may reflect agreement, disagreement or some of each. The optimum number of participants depends on the number needed to have a representative pooling of views (Ndour, Force, & McLaughlin, 1992).

The coaches had selected 60% as a threshold value for the POAs in each position. This value was agreed upon after two rounds of Delphi where the coaches had shared their preferences and threshold values with each other anonymously. The similarities and differences among the threshold values suggested by different coaches were discussed and they were able to reach a consensus on the selected threshold value. The POA of the four chosen defenders in combination (5, 2, 7, 1) was more than 60% ($z = 75.9\%$) and therefore this arrangement was considered acceptable. After arranging the defenders, the above procedures were employed for the midfielders and the forwards. Eventually, the final arrangement presented in Table 9 was developed. A schematic representation of the final 4–4–2 team formation is also shown in Fig. 10. According to the method proposed in this study, the 4–4–2 formation with four defenders (5, 2, 7, 1), four midfielders (12, 14, 13, 81), and two forwards (18, 20) was proposed to the coaches as the best team formation for the upcoming league championship game.

5. Conclusions and future research directions

Contemporary sports impose greater requirement on player selection and team formation strategies (Trninic, Papic, Trninic, & Vukicevic, 2008). The process of player selection and team formation in multi-player sports is a complex multi-criteria decision-making problem with conflicting objectives. Coaches are required to consider a large number of qualitative and quantitative attributes in the player selection process. In spite of the importance of using structured and analytical methods for player selection and team formation, very little research has been conducted on the subject in sports science. We proposed a two-phase framework for player selection and team formation in soccer. The players were selected in the first phase and the best combinations of the selected players were evaluated with a FIS for team formation. We presented a case study to demonstrate the applicability of the proposed framework and exhibit the efficacy of the procedures and algorithms. The contribution of the proposed method is threefold: (1) it addresses the gaps in the sport science literature on the effective and efficient player selection and team formation; (2) it considers imprecise or vague judgments which lead to ambiguity in the decision process; and (3) it uses a meaningful and robust multi-criteria model to aggregate both qualitative judgments and quantitative data.

The proposed framework does not imply a higher-level of 'accuracy' in player selection and team formation. While our approach enables the coaches to assimilate the precise data and imprecise or ambiguous judgments into a formal systematic approach, it should be used with care and in conjunction with the game objectives. Our approach helps the coaches to think systematically about complex multi-criteria decision making problems and improves the quality of their decisions. The coaches' judgment is an integral component of player evaluation; therefore, the effectiveness of the model relies heavily on the cognitive capabilities of the coaches.

Although the case study in this paper considered two factors as inputs in the FIS, the approach permits a large degree of flexibility to integrate additional factors in the evaluation process. The methodology discussed in this paper is not only suitable for multi-player sports, it is also appropriate for modeling workgroups and project teams in business and industry. In conclusion, we stress that our contribution addresses yet a small part of the issues that are involved with arranging players in multi-player sports. It is safe to say that quantitative and analytical player selection and team formation as a discipline is at its infancy. Therefore, we hope that the study presented here can inspire others to pursue further research in this area.

Acknowledgements

The authors would like to thank the anonymous reviewers and the editor for their insightful comments and suggestions.

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