A MATHEMATICAL MODEL USING AHP PRIORITIES FOR SOCCER PLAYER SELECTION: A CASE STUDY

E. Ozceylan[1]

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Contact details
*   Corresponding author
   erenozceylan@gmail.com

Author affiliations
1   Department of Industrial
   Engineering, Gaziantep
   University, Turkey

ABSTRACT

The process of player selection in multi-player sports like soccer is a complex multi-criteria problem. In this paper, a two-phase approach is proposed for soccer player selection. In the first phase, the attributes of each player – based on their position within a soccer team – is prioritised using the Analytic Hierarchic Process (AHP). In the second phase, a 0-1 integer linear programming model is developed using the weights of player attributes, and the top performers are determined for inclusion in the team. Finally, a case study on the Turkish soccer club called Fenerbahçe is used to illustrate the applicability and performance of the proposed approach.

OPSOMMING

Die proses van speler-seleksie in spansporte soos sokker is ’n ingewikkelde, multikriteria probleem. ’n Twee-fase benadering om die kies van spelers vir ’n sokkerspan word voorgestel. In die eerste fase word die eienskappe van die speler prioritiseer deur ’n analitiese hiërargie proses. Die prioritisering is gebaseer op hulle posisie in die span. In die tweede fase word ’n binêre lineêre programmerings-model ontwikkel deur gewigte aan ’n speler se eienskappe toe te ken. Toppresteerders word so identifiseer en in die span ingesluit. Laastens word ’n gevallestudie op die Turkse klubspan Fenerbahçe gebruik om die toepaslikheid en vertoning van die voorgestelde benadering te bepaal.

1   INTRODUCTION

In any sport, formation of a good team is vital to its success. Player selection for a team in most sports is a subjective issue, commonly based on the coaches' notions of what is needed to form the best team. Poor team selection lead to failure, costing a soccer team a trophy or a championship, not to mention the money; and the selection committee and the sport's organising authorities will be accountable to the people who love sport. Poor team selection can also affect the loyalty of players due to non-optimal and combinations of players.

Selection of players in a team is always a difficult task because a large number of qualitative and quantitative attributes in the player selection process need to be taken into account [1]. Thus a systematic approach such as mathematical modelling or the multi-criteria decision-making (MCDM) approach is essential. Although team management uses a variety of assessments such as testing, practice matches, and coaches' judgments to select and evaluate players, quantitative approaches could greatly benefit the team management and be significantly useful [2]. To avoid the traditionally vague and subjective practice of team selection, quantitative approaches could provide more objective results in a shorter time-frame.

In this paper, a two-phase approach is applied to select the best soccer players from within a particular team. In the first phase, the criteria of each player based on their position within the team are prioritised using AHP. In the second phase, a 0-1 integer linear programming model is

developed, and the top performers are determined using the weights of the player criteria. To the best knowledge of the authors, this is the first study that combines AHP and mathematical modelling approaches to evaluate and select soccer players. The AHP methodology, integrated with the integer programming model, has been adopted as an alternative to the conventional and singular methods of weight derivation in AHP.

The remainder of this paper is organised as follows. In Section 2, a literature review is presented. In Section 3, an overview of the evaluation criteria is provided. In Section 4, attribute weights are estimated by AHP, and the details of the proposed approach are presented. In Section 5, the mathematical model for soccer player selection is presented. In Section 6, a case study to illustrate the effectiveness and applicability of the proposed approach is presented. Finally, in Section 7, the conclusions and future research directions are provided.

2 LITERATURE REVIEW

Many researchers have applied various models to team selection, such as the genetic algorithm [2,3], mathematical programming [4,5], ordered weighted averaging [6], AHP [7], and a fuzzy inference system [1]. Omkar and Verma [8] developed a solution approach based on the genetic algortihm to select players for a cricket team. A linear optimisation model for the optimal line-up of a volleyball team was developed by Boon and Sierksma [4]. Their proposed model was used to help coaches determine the optimal line-up of teams and to help scouting crews to assess and hire new players [4]. However, evaluation criteria were ignored in their model [4]. Merigo and Gil-Lafuente [6] used an ordered weighted averaging operator to select a football player from alternatives for a team in a transfer season. To do so, they considered the use of the Hamming distance, the adequacy coefficient, and the index of maximum and minimum level [6].

Gerber and Sharp [9] describe the ability-indexing and integer programme used, and discuss the results of an empirical study conducted using the statistics of 32 South African cricket players. Sharp *et al.* [5] develop an integer programming approach to determine the optimal cricket team by quantifying cricket players' performance based on their ability. Kamble *et al.* [7] present a procedure for selecting cricket team players in complex situations using AHP. Tavana *et al.* [1] propose a two-phase framework for player selection and team formation in soccer. The first phase in their study evaluates the alternative players with a fuzzy ranking method, and selects the top performers for inclusion in the team [1]. The second phase evaluates the alternative combinations of the selected players with a fuzzy inference system, and selects the best combinations for team formation [1]. Ahmed *et al.* [3] apply multi-objective optimisation and decision-making approaches to cricket team selection. They propose a novel gene representation scheme and a multi-objective approach that uses the genetic algorithm to optimise the overall batting and bowling strength of a team with 11 players as variables [3].

Amin and Sharma [10] suggest a new method for cricket team selection that uses the data envelopment analysis (DEA). They propose a DEA formulation for the evaluation of cricket players with different capabilities using multiple outputs [10]. This evaluation differentiates the efficient and inefficient cricket players, and ranks them on the basis of DEA scores [10]. Sarda *et al.* [2] present a solution approach based on the genetic algorithm to find the optimal solution for the problem of football team selection and formation. Their proposed model combines the generally used quantitative approach with attributes based on personal performance, team performance, and the collaborative performance of a player in the presence of other players in the team. It is clear that the current literature on player selection in multi-player sports, especially in soccer, is very limited and scattered. The contribution of the proposed method is twofold: (1) it fills the gap in the literature with regard to quantitative applications that enable effective and efficient player selection and team formation; (2) it applies a hybrid approach that combines AHP and the 0-1 integer programming model to select soccer players.

3 EVALUATION CRITERIA

In general, there are six different positions in a soccer team: goalkeeper, defensive centres, fullbacks, midfielder centres, wings, and forward centres. The location of these positions on a soccer pitch is shown in Figure 1.

It is clear that each position has different criteria. For instance, while the criterion 'tendency to punch' is very important for goalkeepers, it does not make sense if applied to forward centres. So, relevant criteria must be assigned for each position. To do so, twenty criteria are determined for each position from the famous 'Football Manager 2015' computer game. While Figure 2 summarises the criteria of each position for soccer player evaluation, each criterion in the model, and all their definitions, are provided in Table 1. As seen from Figure 2, some of the criteria are common (e.g., anticipation, agility, and first touch), while other criteria are unique to particular positions (e.g., one-on-ones and aerial ability for the goalkeeper position).

Figure 1: 4-4-2 format on a soccer pitch

Criteria for Goalkeepers	Criteria for Fullbacks	Criteria for Defensive Centres
Aerial Ability	Acceleration	Acceleration
Agility	Anticipation	Aggression
Anticipation	Balance	Agility
Bravery	Concentration	Anticipation
Command of Area	Corners	Balance
Communication	Crossing	Bravery
Composure	Decisions	Composure
Concentration	Dribbling	Concentration
Decisions	Flair	Decisions
Eccentricity	Long Throws	Determination
First Touch	Marking	Heading
Handling	Natural Fitness	Jumping
Jumping	Off the Ball	Leadership
Kicking	Pace	Marking
One on Ones	Positioning	Passing
Positioning	Stamina	Positioning
Reflexes	Tackling	Stamina
Rushing Out	Teamwork	Strength
Tendency to Punch	Technique	Tackling
Throwing	Work Rate	Teamwork

Figure 2: Evaluation criteria for each position

Criteria for Midfielder Centres	Criteria for Wings	Criteria for Forward Centres
Acceleration	Acceleration	Acceleration
Aggression	Agility	Agility
Anticipation	Anticipation	Anticipation
Bravery	Balance	Balance
Composure	Crossing	Composure
Decisions	Decisions	Decisions
Determination	Determination	Determination
Dribbling	Dribbling	Dribbling
First Touch	Finishing	Finishing
Flair	First Touch	First Touch
Leadership	Flair	Flair
Long Shots	Long Shots	Heading
Marking	Natural Fitness	Jumping
Off the Ball	Off the Ball	Long Shots
Passing	Pace	Off the Ball
Positioning	Passing	Pace
Stamina	Stamina	Passing
Strength	Teamwork	Stamina
Teamwork	Technique	Technique
Technique	Work Rate	Work Rate

Figure 2 (continues): Evaluation criteria for each position

Table 1: Definitions of each criterion [11]

Criterion	Definition
Acceleration	How fast a player can reach his/her maximum speed.
Aerial ability	A goalkeeper's ability to deal with the ball in aerial situations such as punching and catching.
Aggression	A player's attitude in terms of playing mentality. An aggressive player will look to be more involved in every incident and get stuck in.
Agility	A player's ability to start, stop, and move in different directions at varying levels of speed.
Anticipation	A player's ability to have a sense of the unfolding events and predict what will happen and react to it.
Balance	This controls how long a player can stay on his/her feet under pressure.
Bravery	How committed the player is. Braver players will risk injuries in situations that less brave players will shy away from.
Command of area	How well the goalkeeper takes charge of his/her penalty area and works with his/her defensive line.
Communication	How well a goalkeeper communicates with his/her defensive line and organises the defensive side of the team.
Composure	A player's steadiness of mind and ability, particularly with the ball.
Concentration	A player's concentration on an event-by-event basis.
Corners	Accuracy of a corner kick.
Crossing	A player's proficiency at crossing the ball from wide into the penalty box.
Decisions	A player's ability to make correct decisions most of the time.
Determination	Predictions a player's commitment to success.
Dribbling	A player's ability to dribble the ball.
Eccentricity	The likelihood that the goalkeeper will do the unexpected and act completely unlike a goalkeeper.
Finishing	A player's ability to put the ball in the back of the net when presented with a chance.
First touch	A player's ability to take control of the ball and put it into a useful position, no matter how much pressure there is from the opposite team.
Flair	A player's ability to do the unpredicted and use his/her creativity in an attacking outlet.
Handling	How securely the goalkeeper holds on to the ball when making a save or retrieving a loose ball.
Heading	A player's ability to head the ball in all aerial situations.
Jumping	How good a player is at reaching the ball in the air.
Kicking	The physical ability of a goalkeeper to kick the ball. This purely defines the distance that the player can reach.
Leadership	A player's ability to influence the team and affect events or players without any intentional effort.
Long shots	The player's prowess at shooting from a distance, such as from outside the penalty area.
Long throws	A player's ability to take long throws.
Marking	A player's ability to mark the opposite player.

Table 1 (continues): Definitions of each criterion [11]

Natural fitness	How good the player's fitness is, and how good it stays when not training or when injured.
Off the ball	How well the player uses space when not in possession of the ball.
One-on-ones	The ability of the goalkeeper to do well when faced with an opponent in a one-on-one situation.
Pace	A player's top speed.
Passing	A player's ability to pass the ball.
Positioning	A player's ability to read situations and position himself/herself in the best possible manner to deal with unfolding events.
Reflexes	How good the goalkeeper is at making instinctive reaction saves.
Rushing out	How good the goalkeeper is at coming off his/her line to react to through balls and similar situations.
Stamina	How well a player can endure high-level physical activity for a longer period of time.
Strength	A player's ability to exert his/her physical force on an opponent to his/her benefit.
Tackling	How good the player will be at winning the ball cleanly without conceding fouls.
Teamwork	How well a player follows tactical instructions and works for the team.
Technique	A player's aesthetic quality when passing the ball, shooting, or crossing; or how refined a player will be with the ball.
Tendency to punch	Whether a goalkeeper will catch the ball when he/she can, or punch it clear.
Throwing	How good the goalkeeper's distribution of the ball with his/her arms is.
Work rate	The player's mental drive to work hard.

4   THE ANALYTIC HIERARCHIC PROCESS FOR ESTIMATING ATTRIBUTE WEIGHTS

The Analytic Hierarchy Process (AHP) method was developed by Saaty [12]. AHP assumes that evaluation criteria can be completely expressed in a hierarchical structure. The data acquired from the decision-makers is pairwise comparisons of the relative importance of each of the criteria, or the degree of preference of one factor over another with respect to each criterion [13]. AHP has the advantage of permitting a hierarchical structure of the criteria, which provides users with a better focus on specific criteria and sub-criteria when allocating the weights. The AHP modelling process involves three phases: structuring the decision problem, pairwise comparison, and calculating the priorities of each criterion. Using this three-phase approach, the priorities of the criteria for each position that will be an input for the mathematical model are obtained. It is noted that AHP is used to find only the priorities of each criterion, not to select the best soccer player among alternatives. Selection will be done by a mathematical model that will be given in the next section.

4.1   Structuring the decision problem

There are six different goals in the decision problem: to select the best soccer players for the six different positions – goalkeepers, defensive centres, fullbacks, midfielder centres, wings, and forward centres. This phase involves formulating an appropriate hierarchy of the AHP model that consists of the goal and the criteria. As seen in Figure 2 above, there are twenty criteria for each goal.

4.2   Pairwise comparison

After building the AHP hierarchy, the next phase is the pairwise comparison, which involves forming a team of experts. The nine-point scale, as shown in Table 2, is used to assign pairwise comparisons of all criteria in each position of the hierarchy.

Table 2: The fundamental scale of absolute numbers [14]

Intensity of Importance	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favour one criterion over another
5	Strong importance	Experience and judgment strongly favour one criterion over another
7	Very strong importance	A criterion is favoured very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one criterion over another is of the highest possible order of affirmation

2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it
Reciprocals of above	If criterion *i* has one of the above non-zero numbers assigned to it when compared with criterion *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption

Usually, every member assigns his/her pairwise comparisons, which will be translated into the corresponding pairwise comparison judgment matrices. As suggested by Saaty [14], the geometric mean approach is used to combine the individual judgment matrices to obtain the consensus for the entire expert group. The expert group consists of three academicians from the Physical Education and Sports School at the Gaziantep University; these academics have lots of information on and expertise in soccer and soccer players. Face-to-face interviews were used to collect the pairwise comparison judgments from the experts. Tables 3 to 8 give pairwise comparison matrices of the main criteria for particular positions. It is noted that the geometric means of the three experts were rounded up.

4.3   Calculating the priorities

After the pairwise comparison, the last step is calculating the priorities of each criterion. The software system called Expert Choice 11.0 was used to determine the priority weights; the obtained priority weights are given in Tables 9 and 10. The consistency ratio (CR) of each position is also shown below each table. It should be noted that the quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments. It can be seen that the consistency ratio of each of the pairwise comparisons is equal to or less than 0.04, which is well below the rule-of-thumb value of CR = 0.1. This clearly implies that the evaluators are consistent in assigning pairwise comparison judgments. It is noted that the AHP is based on the fundamental assumption of preferential independence between the decision criteria shown in Figure 2. Details about the various steps of AHP, and especially the mathematical background of AHP, can be found in the literature [15,16]; free and open source software can also be downloaded from http://expertchoice.com/.

5   MATHEMATICAL MODEL FOR SOCCER PLAYER SELECTION

The proposed mathematical model for soccer player selection is introduced in this section.

Sets and Indices

P   is the set of all players. The index j will be used as the index for the set of players
G   is the set of goalkeepers. Note that $G \in P$
D   is the set of defensive centre players. Note that $D \in P$
B   is the set of fullback players. Note that $B \in P$
M   is the set of midfielder centre players. Note that $M \in P$
W   is the set of wing players. Note that $W \in P$
F   is the set of forward centre players. Note that $F \in P$
S   is the set of foreign players. Note that $S \in P$
R   is the set of positions in the team. 1 is defined as a goalkeeper, 2 as a defensive centre, 3 as a fullback, 4 as a midfielder centre, 5 as a wing, and 6 as a forward centre. The index i will be used as the index for the set of positions.
C   is the set of criteria. The index c will be used as the index for the set of criteria.

Variables

X_{ji} A binary variable equal to 1 if player $j \in P$ is assigned to position $i \in R$; otherwise it is 0

Table 3: Pairwise comparison matrix for the criteria specific to the goalkeeper

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20		Criteria
C1	1	3	1	1/2	5	1	2	1	4	1/3	1/4	1	4	1/5	1/4	1/3	1/3	2	1	1/2	C1	Rushing Out
C2		1	1/2	1/5	1/5	1/3	1	1/5	2	1/7	1/8	1/2	2	1/5	1/5	1/6	1/8	1/2	1/3	1/6	C2	Kicking
C3			1	1	3	1	1	2	3	1/5	1/3	1	4	1/4	1/3	1/4	1/5	1	1/3	1/4	C3	One on Ones
C4				1	3	1	1	4	5	1/2	1/5	1	5	1/5	1/4	1/4	1/3	1	1/4	1/5	C4	Command of Area
C5					1	1/3	1/5	2	3	1/6	1/7	1/3	4	1/5	1/6	1/7	1/8	1/3	1/4	1/5	C5	Eccentricity
C6						1	1/2	4	6	1/3	1/3	1	6	1/2	1/3	1/4	1/5	1	1/2	1/2	C6	Handling
C7							1	5	7	1/3	1/3	3	6	1	1/3	1/5	1/4	3	1	1	C7	Aerial Ability
C8								1	3	1/7	1/7	1/3	2	1/5	1/9	1/8	1/7	1/3	1/5	1/5	C8	Communication
C9									1	1/6	1/6	1/5	1/2	1/6	1/8	1/8	1/7	1/5	1/5	1/4	C9	First Touch
C10										1	2	4	1	1/2	1/2	1	2	2	2	2	C10	Reflexes
C11											1	3	5	1	1/2	1/2	1	3	3	3	C11	Throwing
C12												1	3	1/5	1/7	1/7	1/3	1	1	1	C12	Tendency to Punch
C13													1	1/6	1/7	1/7	1/8	1/3	1/3	1/2	C13	Bravery
C14														1	2	1/2	1/2	3	2	3	C14	Decisions
C15															1	1	1	6	4	4	C15	Concentration
C16																1	1	4	3	2	C16	Anticipation
C17																	1	4	3	2	C17	Positioning
C18																		1	1/3	1/2	C18	Composure
C19																			1	1	C19	Agility
C20																				1	C20	Jumping

Table 4: Pairwise comparison matrix for the criteria specific to defensive centres

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20		Criteria
C1	1	1/3	4	1/6	1/3	3	6	6	1/3	2	1/5	1/5	1/3	4	1	1/3	3	1	2	1/2	C1	Heading
C2		1	5	1/2	1	2	3	3	1	2	1/2	1/2	1	3	3	1	4	2	6	3	C2	Marking
C3			1	1/6	1/3	1/3	1/2	1/2	1/5	1/4	1/8	1/5	1/5	1/3	1	1/4	2	1/3	3	1/4	C3	Passing
C4				1	3	3	4	4	1	1	1/3	1	1	1	4	1	6	2	7	3	C4	Tackling
C5					1	1	2	2	1/4	1/5	1/8	1/3	1/3	1/4	1	1/5	2	1	3	1	C5	Aggression
C6						1	2	2	1/5	1/4	1/7	1/5	1/5	1/6	1	1/5	3	1	3	1	C6	Bravery
C7							1	1	1/6	1/7	1/8	1/6	1/7	1/5	1/2	1/5	3	1	3	1/2	C7	Decisions
C8								1	1/5	1/5	1/6	1/6	1/5	1/3	1/5	1/4	3	1	3	1/2	C8	Determination
C9									1	1	1	1/2	1	1/2	1	2	6	4	5	3	C9	Concentration
C10										1	1	1/2	1	1	1	3	5	4	5	3	C10	Leadership
C11											1	1/2	1	1	1/2	3	5	4	4	1	C11	Anticipation
C12												1	2	4	1	5	7	6	5	4	C12	Positioning
C13													1	3	1/3	3	5	4	3	3	C13	Composure
C14														1	1/6	1/3	2	2	1	1/6	C14	Teamwork
C15															1	5	6	5	3	4	C15	Agility
C16																1	2	1	1/3	1/4	C16	Stamina
C17																	1	1/4	1/6	1/7	C17	Balance
C18																		1	2	1	C18	Strength
C19																			1	1/3	C19	Acceleration
C20																				1	C20	Jumping

Table 5: Pairwise comparison matrix for the criteria specific to fullbacks

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20		Criteria
C1	1	5	1/3	1	2	1/2	3	1	2	4	3	1	2	1	2	3	3	1/3	1/5	1/2	C1	Dribbling
C2		1	1/5	1/4	1/2	1/6	1/2	1/5	1/3	1	1/2	1/5	1/8	1/3	1/2	1/6	1/2	1/7	1/8	1/5	C2	Corners
C3			1	2	3	1	4	1	2	5	3	1	1/2	2	5	1/3	3	1/3	1/3	1	C3	Marking
C4				1	3	1	3	2	2	4	2	2	2	3	3	4	2	1/2	1	1/3	C4	Crossing
C5					1	3	1	4	2	2	1	3	4	2	1	3	2	4	6	4	C5	Technique
C6						1	5	2	1	4	3	1	2	3	6	1	3	1	1	1	C6	Tackling
C7							1	1/3	1/6	1	1/2	1/6	1/2	1/2	2	1/5	1/2	1/4	1/3	1/4	C7	Long Throws
C8								1	1/3	4	1	1/3	2	2	6	1	2	1	1	1/2	C8	Work Rate
C9									1	6	4	1	3	3	7	3	4	3	3	2	C9	Decisions
C10										1	1/3	1/6	1/4	1/4	2	1/3	1/4	1/3	1/3	1/6	C10	Concentration
C11											1	1/3	1	1	4	1	1	1	1	1/2	C11	Anticipation
C12												1	3	3	6	4	4	3	4	2	C12	Flair
C13													1	1	3	2	1	1	2	1/2	C13	Positioning
C14														1	3	2	1	1	3	1/3	C14	Teamwork
C15															1	1/3	1/3	1/3	1	1/9	C15	Off the Ball
C16																1	1	1	4	1/3	C16	Stamina
C17																	1	1	1/4	1	C17	Balance
C18																		1	3	4	C18	Pace
C19																			1	2	C19	Acceleration
C20																				1	C20	Natural Fitness

Table 6: Pairwise comparison matrix for the criteria specific to midfielder centres

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20		Criteria
C1	1	4	2	1/4	1/3	1	3	2	1/4	3	1/2	1/3	1/2	1/2	1	1/3	1/5	2	1	2	C1	Dribbling
C2		1	1/2	1/4	1/7	1/5	1/2	1/3	1/4	1/4	1/6	1/7	1/6	1/6	1/3	1/7	1/5	1/2	1/2	1/2	C2	First Touch
C3			1	1/2	1/3	1/4	1	1/2	1/2	1/3	1/2	1/3	1/4	1/4	1/2	1/6	1/3	1	1	1/2	C3	Marking
C4				1	1/2	1/3	3	1	2	1/2	1	1/2	1/4	1/3	1	1/5	1/3	3	2	1	C4	Passing
C5					1	1/2	6	2	4	1	2	1	1/3	1/2	2	1/5	1/2	5	4	2	C5	Technique
C6						1	7	4	6	2	4	2	1/2	1	4	1/4	1	1/8	1/6	1/4	C6	Long Shots
C7							1	1/3	1/4	1/4	1/2	1/5	1/8	1/5	1/6	1/7	1/5	1/8	1/8	1/5	C7	Aggression
C8								1	1	1	2	1/2	1/4	1/2	1/2	1/3	1	1/3	1/3	1	C8	Bravery
C9									1	1	1	1/3	1/4	1/2	3	1/4	1	1/5	1/4	1/4	C9	Decisions
C10										1	4	1/3	1/4	1/2	1/2	1/4	1	1/2	1/5	1/2	C10	Determination
C11											1	1/5	1/7	1/4	1/4	1/6	1/4	1/5	1/7	1/3	C11	Leadership
C12												1	1/2	2	1/2	1/3	2	1	1/3	2	C12	Anticipation
C13													1	4	1/4	1	4	2	1	5	C13	Flair
C14														1	1	1/4	1	1/2	1/5	2	C14	Positioning
C15															1	1/6	1	1/3	1/5	3	C15	Composure
C16																1	5	2	1	5	C16	Teamwork
C17																	1	1/4	1/5	1	C17	Off the Ball
C18																		1	1	3	C18	Stamina
C19																			1	1	C19	Strength
C20																				1	C20	Acceleration

Table 7: Pairwise comparison matrix for the criteria specific to wings

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20		Criteria
C1	1	1/5	1	1/6	1/3	1/5	1/2	1/3	2	2	1/2	1/4	1/2	1/5	1/4	1/2	1/3	1/5	1/5	1/4	C1	Finishing
C2		1	5	1	2	3	2	6	5	1	1	2	1	2	1	2	1	1	1	1	C2	Dribbling
C3			1	1/3	1/3	1/6	1/2	1/2	2	2	1/4	1/4	1/3	1/4	1/3	4	1/3	1/4	1/4	1/3	C3	First Touch
C4				1	1	1/3	2	2	4	4	1/2	1/2	1	1/2	1	2	1	1/2	1/2	1	C4	Crossing
C5					1	1/2	2	2	4	4	1/2	1/2	1	1/2	1	1/2	1	1/2	1/2	1	C5	Passing
C6						1	2	2	3	5	1/2	1/2	1	1/2	1	1/2	1	1/2	1/2	1	C6	Technique
C7							1	1	2	3	1/4	1/4	1/2	1/3	1/5	1/5	1	1/6	1/5	1/3	C7	Long Shots
C8								1	3	3	1/4	1/4	1/2	1/6	1/4	1/5	1	1/6	1/5	1/5	C8	Work Rate
C9									1	1	1/6	1/6	1/3	1/8	1/5	1/4	1/2	1/4	1/4	1/3	C9	Decisions
C10										1	1/4	1/5	1/3	1/6	1/6	1/5	1/3	1/5	1/5	1/4	C10	Determination
C11											1	1	2	1/2	1/2	1	3	1	1	2	C11	Anticipation
C12												1	3	1/2	1/3	1	3	1	2	3	C12	Flair
C13													1	1/5	1/6	1/3	1	1/3	1/2	1	C13	Teamwork
C14														1	1	2	5	2	3	4	C14	Off the Ball
C15															1	2	5	2	3	4	C15	Agility
C16																1	3	1	2	3	C16	Stamina
C17																	1	1/4	1/2	1	C17	Balance
C18																		1	3	4	C18	Pace
C19																			1	1	C19	Acceleration
C20																				1	C20	Natural Fitness

Table 8: Pairwise comparison matrix for the criteria specific to forward centres

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20		Criteria
C1	1	6	3	2	4	2	3	2	2	3	3	2	2	2	4	3	4	2	3	4	C1	Finishing
C2		1	1/5	1/4	1/2	1/5	1/2	1/3	1/7	1/2	1/6	1/6	1/3	1/6	1/8	1/2	1/4	1/3	1/7	1/4	C2	Dribbling
C3			1	2	3	1	3	1	1/3	2	1/2	1	2	1/2	2	3	1	2	2	2	C3	First Touch
C4				1	5	1/3	4	1	44	5	1/3	1/2	3	1/3	1	2	1/2	1	1	3	C4	Heading
C5					1	1/4	1	1/3	1/3	1/2	1/5	1/4	1/2	1/6	1/6	1	1/4	1/2	1/5	1/4	C5	Passing
C6						1	5	2	3	3	1	1	2	1/2	4	4	1	2	2	4	C6	Technique
C7							1	1/3	1/6	1/2	1/4	1/4	1/2	1/5	1/8	1	1/4	1/2	1/6	1/5	C7	Long Shots
C8								1	1/3	2	1/2	1/2	2	1/2	1	3	1/2	2	2	1/2	C8	Work Rate
C9									1	3	1/4	1/5	3	1/3	1	2	3	1	1	3	C9	Decisions
C10										1	1/4	1/5	1	1/4	1/5	3	1/4	1	1/5	1/3	C10	Determination
C11											1	1	4	1	4	7	1	4	4	3	C11	Anticipation
C12												1	4	1	5	7	1	4	4	4	C12	Flair
C13													1	1/4	1/8	2	1/4	1	1	2	C13	Composure
C14														1	5	5	1	4	4	2	C14	Off the Ball
C15															1	1	1/4	1	1/3	1	C15	Agility
C16																1	1/5	1	1/3	1	C16	Stamina
C17																	1	5	3	1	C17	Balance
C18																		1	1/3	2	C18	Pace
C19																			1	2	C19	Acceleration
C20																				1	C20	Jumping

Table 9: Priority weights for goalkeepers, defensive centres, and fullbacks

Goalkeeper		Defensive Centres		Fullbacks	
Criteria	Priority	Criteria	Priority	Criteria	Priority
Rushing Out	0.034	Heading	0.043	Dribbling	0.057
Kicking	0.014	Marking	0.069	Corners	0.012
One on Ones	0.027	Passing	0.016	Marking	0.070
Command of Area	0.034	Tackling	0.084	Crossing	0.072
Eccentricity	0.017	Aggression	0.031	Technique	0.097
Handling	0.033	Bravery	0.024	Tackling	0.063
Aerial Ability	0.045	Decisions	0.017	Long Throws	0.018
Communication	0.015	Determination	0.017	Work Rate	0.042
First Touch	0.009	Concentration	0.073	Decisions	0.081
Reflexes	0.079	Leadership	0.070	Concentration	0.014
Throwing	0.092	Anticipation	0.093	Anticipation	0.033
Tendency to Punch	0.030	Positioning	0.110	Flair	0.086
Bravery	0.011	Composure	0.074	Positioning	0.042
Decisions	0.083	Teamwork	0.045	Teamwork	0.038
Concentration	0.122	Agility	0.081	Off the Ball	0.017
Anticipation	0.119	Stamina	0.048	Stamina	0.047
Positioning	0.106	Balance	0.010	Balance	0.029
Composure	0.027	Strength	0.024	Pace	0.067
Agility	0.048	Acceleration	0.021	Acceleration	0.055
Jumping	0.054	Jumping	0.050	Natural Fitness	0.060
Inconsistency	0.020	Inconsistency	0.030	Inconsistency	0.040

Table 10: Priority weights for midfielder centres, wings, and forward centres

Midfielder Centres		Wings		Forward Centres	
Criteria	Priority	Criteria	Priority	Criteria	Priority
Dribbling	0.037	Finishing	0.016	Finishing	0.110
First Touch	0.011	Dribbling	0.073	Dribbling	0.010
Marking	0.019	First Touch	0.028	First Touch	0.052
Passing	0.044	Crossing	0.050	Heading	0.052
Technique	0.073	Passing	0.042	Passing	0.014
Long Shots	0.061	Technique	0.057	Technique	0.076
Aggression	0.009	Long Shots	0.022	Long Shots	0.014
Bravery	0.025	Work Rate	0.023	Work Rate	0.040
Decisions	0.031	Decisions	0.012	Decisions	0.058
Determination	0.030	Determination	0.011	Determination	0.020
Leadership	0.019	Anticipation	0.056	Anticipation	0.094
Anticipation	0.054	Flair	0.076	Flair	0.096
Flair	0.098	Teamwork	0.034	Composure	0.026
Positioning	0.049	Off the Ball	0.110	Off the Ball	0.095
Composure	0.053	Agility	0.099	Agility	0.045
Teamwork	0.128	Stamina	0.068	Stamina	0.018
Off the Ball	0.046	Balance	0.031	Balance	0.072
Stamina	0.077	Pace	0.087	Pace	0.028
Strength	0.095	Acceleration	0.062	Acceleration	0.047
Acceleration	0.041	Natural Fitness	0.043	Jumping	0.033
Inconsistency	0.020	Inconsistency	0.010	Inconsistency	0.030

Parameters

V_{ic} Score of criterion $c \in C$ of player $j \in P$
W_{rc} Priority of criterion $c \in C$ of position $i \in R$
A_j Age of player $j \in P$
C_j Weekly cost of player $j \in P$
Ps_j Penalty kicking score of player $j \in P$
Fs_j Free kick score of player $j \in P$
N_i Maximum number of players who play in position $i \in R$
U Upper limit of average age of the first eleven
B Upper limit of weekly budget for team up
P Lower limit of penalty kicking score of the first eleven
F Lower limit of free kick score of the first eleven
Q Upper limit of number of foreign players in the first eleven

Using the notation, the mathematical model is presented below, starting with the objective function.

Objective function

$$Z = \text{Maximise } \sum_j^P \sum_i^R \sum_c^C X_{ji} V_{jc} W_{ic} \tag{1}$$

Subject To

$$\sum_i^R X_{ji} \leq 1 \qquad \forall_{j\in P} \tag{2}$$
$$\sum_j^G X_{ji} \leq N_{i=1} \tag{3}$$
$$\sum_j^D X_{ji} \leq N_{i=2} \tag{4}$$
$$\sum_j^B X_{ji} \leq N_{i=3} \tag{5}$$
$$\sum_j^M X_{ji} \leq N_{i=4} \tag{6}$$
$$\sum_j^W X_{ji} \leq N_{i=5} \tag{7}$$
$$\sum_j^F X_{ji} \leq N_{i=6} \tag{8}$$
$$\sum_j^P \sum_i^R X_{ji} A_j \leq 11U \tag{9}$$
$$\sum_j^P \sum_i^R X_{ji} C_j \leq B \tag{10}$$
$$\sum_j^P \sum_i^R X_{ji} Ps_j \geq P \tag{11}$$
$$\sum_j^P \sum_i^R X_{ji} Fs_j \geq F \tag{12}$$
$$\sum_j^S X_{ji} \leq Q \tag{13}$$
$$X_{ji} \in \{0,1\} \qquad \forall_{j\in P, i\in R} \tag{14}$$

The objective function minimises the total value of the players' talent. Constraint 2 ensures that each player must be assigned to only one position if the player is chosen. Constraints 3-8 provide that 11 players are selected for the team in line with the maximum available players for each position. Constraint 9 guarantees that the average age of the team must be lower than the upper limit of the average age. Constraint 10 ensures that the weekly cost of the team cannot exceed the club budget. Constraints 11 and 12 guarantee that the penalty and free kick value of the team must be equal to or greater than the lower limit respectively. Constraint 13 ensures that the number of assigned foreign players is equal to or lowers than the upper limit. Constraint 14 represents the binary variables.

6 ILLUSTRATIVE CASE STUDY

In this section, we present a case study to illustrate the effectiveness and applicability of the proposed approach.

6.1 Description of the data

The proposed approach is illustrated with real data obtained from the Fenerbahçe Soccer Club (FSC), a professional soccer team based in Istanbul, Turkey. Fenerbahçe has been in the first division of Turkish soccer since it was founded in 1905, and has never been relegated to lower divisions. The team squad has 30 players who include four goalkeepers, seven defensive centre players, seven fullbacks, twelve midfielder centre players, ten wings, and four forward centre players. Table 11 shows the players with their available positions and other data; as shown in this table, a player can play one or more positions. According to Table 11, Bruno Alves plays as a defensive centre player only, while Mehmet Topuz plays three different positions: fullback, midfielder centre, and wing.

As mentioned earlier, there are twenty criteria for each position. Tables 12-15 give the scores of each criterion for six different player positions. It is noted that 20 is the maximum score for each criterion. All data was obtained from the Football Manager 2015 computer game. Bracketed numbers in Table 12 indicate the same players given in Table 11. $N_{1,2,3,4,5,6}$ are set to 1, 2, 2, 2, 2, and 2. The upper limit of the average age is set to 30, and the weekly budget is US\$ 750,000. The lower limits of penalties and free kicks are 10.

Table 11: Player list and related data

No	Players	Available Positions	Cost in US$	Nation	Age	Penalty	Free Kick
1	Volkan Demirel	Goalkeeper	75000	Local	32	3	10
2	Mert Gunok	Goalkeeper	16000	Local	25	1	10
3	Erten Ersu	Goalkeeper	1100	Local	20	1	7
4	Ertugrul Taskiran	Goalkeeper	2812	Local	24	3	10
5	Michal Kadlec	Fullback, Defensive Centre	63000	Foreign	29	14	14
6	Hasan Ali Kaldırım	Fullback	36000	Local	24	8	4
7	Caner Erkin	Fullback, Wing	43000	Local	25	12	15
8	Serdar Kesimal	Fullback, Defensive Centre	36000	Local	25	11	5
9	Bekir Irtegun	Fullback, Defensive Centre	43500	Local	30	7	4
10	Gokhan Gonul	Fullback, Wing	51000	Local	29	10	4
11	Mehmet Topuz	Fullback, Midfielder Centre, Wing	40000	Local	30	15	13
12	Egemen Korkmaz	Defensive Centre	53000	Local	31	10	6
13	Bruno Alves	Defensive Centre	75000	Foreign	32	12	14
14	Mehmet Topal	Defensive Centre, Midfielder Centre	62000	Local	28	10	7
15	Selcuk Sahin	Defensive Centre, Midfielder Centre	28500	Local	33	8	5
16	Raul Meireles	Midfielder Centre	75000	Foreign	31	12	14
17	Emre Belozoglu	Midfielder Centre	60000	Local	33	16	14
18	Samuel Holmen	Midfielder Centre	39000	Foreign	30	7	8
19	Gokay Irevul	Midfielder Centre	2312	Local	21	8	12
20	Alper Potuk	Midfielder Centre, Wing	45000	Local	23	10	10
21	Salih Ucan	Midfielder Centre	4125	Local	20	12	9
22	Uygar Zeybek	Midfielder Centre, Wing	1100	Local	19	5	6
23	Recep Niyaz	Midfielder Centre	1100	Local	19	10	11
24	Diego Ribas	Midfielder Centre, Wing	105000	Foreign	29	13	15
25	Miroslav Stoch	Wing	54000	Foreign	24	12	13
26	Milos Krasic	Wing	69000	Foreign	29	12	12
27	Dirk Kuyt	Wing, Forward Centre	86000	Foreign	33	13	5
28	Moussa Sow	Wing, Forward Centre	42000	Foreign	28	15	9
29	Pierre Webo	Forward Centre	37500	Foreign	32	14	10
30	Emanuel Emenike	Forward Centre	72000	Foreign	27	12	7

Table 12: Attribute values of goalkeepers and fullbacks

Criteria	Goalkeepers				Criteria	Fullbacks						
	[1]	[2]	[3]	[4]		[5]	[6]	[7]	[8]	[9]	[10]	[11]
Aerial Ability	14	14	12	12	Acceleration	11	16	15	12	13	15	10
Agility	13	14	10	12	Anticipation	14	10	12	12	13	14	11
Anticipation	16	13	7	12	Balance	14	9	13	12	13	11	15
Bravery	16	17	13	13	Concentration	12	11	14	9	10	14	12
Command of Area	16	12	12	12	Corners	12	7	16	2	5	7	11
Communication	10	10	10	8	Crossing	15	10	17	8	7	12	15
Composure	14	13	7	12	Decisions	13	10	9	11	11	14	9
Concentration	9	14	8	12	Dribbling	8	9	14	7	10	12	12
Decisions	15	12	12	11	Flair	8	8	14	8	5	14	9
Eccentricity	13	9	7	6	Long Throws	11	13	6	10	10	15	10
First Touch	9	9	2	8	Marking	13	11	9	12	12	13	12
Handling	17	15	12	13	Natural Fitness	15	16	15	10	12	18	15
Jumping	15	16	14	14	Off the Ball	10	10	12	11	7	12	9
Kicking	17	13	12	17	Pace	14	14	15	12	13	15	10
One on Ones	12	13	10	7	Positioning	15	12	11	12	12	12	9
Positioning	17	14	12	12	Stamina	15	16	16	11	13	15	11
Reflexes	15	15	12	14	Tackling	13	14	12	12	16	16	12
Rushing Out	16	12	14	11	Teamwork	16	13	12	11	12	15	15
Tendency to Punch	10	10	6	13	Technique	10	12	14	12	8	13	13
Throwing	14	12	11	16	Work Rate	15	16	17	10	14	16	15

Table 13: Attribute values of defensive centre and forward centre players

Criteria	Defence Players							Criteria	Forward Players			
	[5]	[8]	[9]	[12]	[13]	[14]	[15]		[27]	[28]	[29]	[30]
Acceleration	11	12	13	10	9	11	11	Acceleration	10	16	12	16
Aggression	12	11	11	17	18	13	14	Agility	14	16	14	16
Agility	10	12	14	8	9	12	9	Anticipation	16	16	14	12
Anticipation	14	12	13	13	16	16	13	Balance	16	16	15	18
Balance	14	12	13	16	14	14	13	Composure	13	16	12	13
Bravery	14	12	15	20	20	12	14	Decisions	15	13	13	9
Composure	12	14	11	10	13	13	13	Determination	18	16	15	13
Concentration	12	9	10	16	14	14	13	Dribbling	10	10	7	13
Decisions	13	11	11	13	12	14	12	Finishing	12	18	14	16
Determination	11	11	13	18	18	12	15	First Touch	15	12	15	13
Heading	13	13	13	16	16	11	14	Flair	10	14	10	15
Jumping	13	12	13	13	16	14	14	Heading	14	14	17	8
Leadership	10	7	11	15	14	5	12	Jumping	12	11	13	13
Marking	13	12	12	17	14	13	15	Long Shots	6	12	8	15
Passing	13	13	9	8	13	13	12	Off the Ball	16	15	15	14
Positioning	15	12	12	13	8	17	16	Pace	10	15	12	18
Stamina	15	11	13	12	13	16	13	Passing	10	10	11	8
Strength	13	12	13	17	18	14	13	Stamina	16	14	13	15
Tackling	13	12	16	14	13	16	15	Technique	12	12	12	14
Teamwork	16	11	12	13	14	18	16	Work Rate	19	15	15	14

Table 14: Attribute values of midfielder centre players

Criteria	Players											
	[11]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]
Acceleration	10	11	11	13	8	12	13	16	7	12	13	12
Aggression	15	13	14	12	17	16	11	13	14	11	5	12
Anticipation	11	16	13	15	17	14	11	11	13	12	11	14
Bravery	18	12	14	10	16	15	8	12	5	7	7	9
Composure	9	13	13	13	17	13	11	12	16	8	12	12
Decisions	9	14	12	14	17	13	10	12	14	7	11	11
Determination	16	12	15	13	19	15	13	14	11	13	13	11
Dribbling	12	9	6	8	11	10	12	16	13	12	14	18
First Touch	13	13	11	14	16	12	13	13	15	11	14	19
Flair	9	8	6	11	16	10	11	14	15	13	17	18
Leadership	9	5	12	12	16	11	7	8	7	10	8	5
Long Shots	14	13	12	15	13	10	8	8	12	11	9	15
Marking	12	13	15	13	10	12	8	9	6	9	3	6
Off the Ball	9	8	11	12	12	14	9	12	11	8	11	11
Passing	13	13	12	14	17	11	14	13	13	12	12	17
Positioning	9	17	16	16	12	13	9	9	6	3	7	7
Stamina	11	16	13	12	10	15	12	15	10	9	6	14
Strength	14	14	13	12	12	10	6	8	7	6	5	9
Teamwork	15	18	16	14	14	18	13	13	13	10	11	13
Technique	13	12	11	14	17	11	14	15	18	13	16	19

Table 15: Attribute values of wings

Criteria	Players									
	[7]	[10]	[11]	[20]	[22]	[24]	[25]	[26]	[27]	[28]
Acceleration	15	15	10	16	12	12	17	14	10	16
Agility	15	15	10	16	12	17	18	14	14	16
Anticipation	12	14	11	11	12	14	7	13	16	16
Balance	13	11	15	9	6	10	7	8	16	16
Crossing	17	12	15	13	13	14	13	13	10	4
Decisions	9	14	9	12	7	11	9	8	15	13
Determination	17	17	16	14	13	11	7	14	18	16
Dribbling	14	12	12	16	12	18	16	14	10	10
Finishing	13	8	11	8	9	16	16	10	12	18
First Touch	14	12	13	13	11	19	14	13	15	12
Flair	14	14	9	14	13	18	15	11	10	14
Long Shots	13	8	14	8	11	15	16	10	6	12
Natural Fitness	15	18	15	14	17	14	14	7	17	12
Off the Ball	12	12	9	12	8	11	11	15	16	15
Pace	15	15	10	14	11	12	14	13	10	15
Passing	15	13	13	13	12	17	14	13	10	10
Stamina	16	15	11	15	9	14	13	12	16	14
Teamwork	12	15	15	13	10	13	10	10	17	14
Technique	14	13	13	15	13	19	16	15	12	12
Work Rate	17	16	15	16	13	13	9	10	19	15

6.2 Computational experiment

The 0-1 integer linear programming formulation (1)–(14) of the sample network contains 44 variables and 43 constraints. All computational experiments are conducted on a notebook computer with Intel Core2 Duo 1.66 GHz and 2 GB RAM. The computation time required to solve the model to optimality using LINDO 14.0 is no more than one CPU second for any of the instances solved. The eleven best players obtained from the results are selected and shown in Figure 3. The total talent value of the first eleven – in other words, the objective function value – is calculated to be 144.689.

As seen from Figure 3, all constraints are satisfied. Five foreign players are selected for the first eleven. The average age, penalty kicking score and free kick score are 29.27, 11.54, and 11.09 respectively. To make a comparison, the last 38 matches of the FSC were investigated. Table 16 shows the first 16 players who take time most on the field. According to Table 13, 8 players out of 11 players who take time most, and 11 players out of 16 players who take time most are in the optimal solution. Players in the optimal solution are highlighted in bold.

Figure 3: Optimal first eleven

Table 16: 16 players who take time most on the field [17]

Rank	Player	Total Time (min)	Rank	Player	Total Time (min)
1	**Mehmet Topal**	3321	9	Bekir Irtegun	2231
2	**Gokhan Gonul**	2938	10	**Alper Potuk**	2080
3	**Caner Erkin**	2790	11	**Emre Belozoglu**	1899
4	**Moussa Sow**	2779	12	**Diego**	1742
5	Dirk Kuyt	2547	13	Michal Kadlec	1615
6	**Volkan Demirel**	2455	14	Egemen Korkmaz	1583
7	**Bruno Alves**	2326	15	**Pierre Webo**	1576
8	Emmanuel Emenike	2232	16	**Raul Meireles**	1515

6.3 Scenario analyses for managerial insights

A number of instances were generated to carry out scenario analyses where problem parameters were changed to determine their impact on the performance measures. Each scenario is given below. It is noted that while changing some of the parameters, the rest of the parameters stay constant.

6.3.1 Scenario#1: Effects of the weekly budget

The first scenario considered was the effect of decreasing the weekly budget of the club on the objective function and the team. The current budget was decreased five times with a 10 per cent decrement each time. Table 17 gives the selected players and objective function values of each run. According to Table 17, decreasing the weekly budget of the club decreases the total talent score of the team, and changes the team distribution, except for forward centre players.

Table 17: Effects of the weekly budget

Positions	US$ 375,000	US$ 450,000	US$ 525,000	US$ 600,000	US$ 675,000	US$ 750,000
Goalkeeper	Ertugrul Taskiran	Mert Gunok	Mert Gunok	Mert Gunok	Volkan Demirel	Volkan Demirel
Defensive C.#1	Bruno Alves	Bruno Alves	Mehmet Topal	Bruno Alves	Bruno Alves	Bruno Alves
Defensive C.#2	Selcuk Sahin	Selcuk Sahin	Selcuk Sahin	Selcuk Sahin	Mehmet Topal	Mehmet Topal
Fullback#1	Caner Erkin	Caner Erkin	Caner Erkin	Caner Erkin	Caner Erkin	Caner Erkin
Fullback#2	Mehmet Topuz	Mehmet Topuz	Michael Kadlec	Gokhan Gonul	Gokhan Gonul	Gokhan Gonul
Midfielder C.#1	Salih Ucan	Salih Ucan	Salih Ucan	Raul Meireles	Raul Meireles	Raul Meireles
Midfielder C.#2	Gokay Iravul	Emre Belozoglu	Emre Belozoglu	Emre Belozoglu	Emre Belozoglu	Emre Belozoglu
Wing#1	Miroslav Stoch	Miroslav Stoch	Miroslav Stoch	Alper Potuk	Alper Potuk	Alper Potuk
Wing#2	Alper Potuk	Alper Potuk	Diego Ribas	Diego Ribas	Diego Ribas	Diego Ribas
Forward C.#1	Moussa Sow	Moussa Sow	Moussa Sow	Moussa Sow	Moussa Sow	Moussa Sow
Forward C.#2	Pierre Webo	Pierre Webo	Pierre Webo	Pierre Webo	Pierre Webo	Pierre Webo
Obj. Function	135.197	139.502	141.628	143.568	144.689	144.689

6.3.2 Scenario#2: Effects of the average age

The other scenario considered was the effect of decreasing the average age of the team on the objective function and the team distribution. The current desired average age was decreased five times, one by one. Table 18 gives the selected players and objective function values of each run. According to Table 18, decreasing the average age of team also decreases the total talent score of the team, as found in the first scenario. The main reason for this is that the talent scores of young players are not as high as those of older players; it is understood that experience is very important for soccer players.

Table 18: Effects of the average age

Positions	25 years old	26 years old	27 years old	28 years old	29 years old	30 years old
Goalkeeper	Erten Ersu	Mert Gunok	Mert Gunok	Volkan Demirel	Volkan Demirel	Volkan Demirel
Defensive C.#1	Michal Kadlec	Bruno Alves	Bruno Alves	Michael Kadlec	Michael Kadlec	Bruno Alves
Defensive C.#2	Mehmet Topal	Mehmet Topal	Mehmet Topal	Bruno Alves	Mehmet Topal	Mehmet Topal
Fullback#1	Mehmet Topuz	Michael Kadlec	Michael Kadlec	Caner Erkin	Caner Erkin	Caner Erkin
Fullback#2	Caner Erkin	Caner Erkin	Caner Erkin	Gokhan Gonul	Gokhan Gonul	Gokhan Gonul
Midfielder C.#1	Gokay Irevul	Salih Ucan	Salih Ucan	Salih Ucan	Raul Meireles	Raul Meireles
Midfielder C.#2	Recep Niyaz	Recep Niyaz	Emre Belozoglu	Emre Belozoglu	Emre Belozoglu	Emre Belozoglu
Wing#1	Alper Potuk	Alper Potuk	Alper Potuk	Alper Potuk	Alper Potuk	Alper Potuk
Wing#2	Miroslav Stoch	Diego Ribas	Miroslav Stoch	Diego Ribas	Diego Ribas	Diego Ribas
Forward C.#1	Moussa Sow	Moussa Sow	Moussa Sow	Moussa Sow	Moussa Sow	Moussa Sow
Forward C.#2	Emanuel Emenike	Emanuel Emenike	Emanuel Emenike	Emanuel Emenike	Pierre Webo	Pierre Webo
Obj. Function	132.321	138.517	141.017	143.447	144.332	144.689

7 CONCLUSION

In this paper, a two-phase solution approach was proposed for soccer player selection. In the first phase, the attributes of each player based on each position were prioritised using AHP. In the second phase, a 0-1 integer linear programming model was developed using the weights of player attributes, and the top performers were determined for inclusion in the team. The proposed solution approach was applied to the Turkish soccer club Fenerbahçe, in order to illustrate the applicability and performance of the approach.

The contribution of the proposed method is twofold: (1) it fills the gaps in the literature with regard to quantitative applications that enable effective and efficient player selection and team formation; (2) it applies a hybrid approach that combines AHP and 0-1 integer programming model to select soccer players for a particular team. It should be accepted that the proposed approach does not imply a higher-level of 'accuracy' in player selection and team formation. However, the authors believe that the proposed approach may help coaches to think systematically about player selection problems and to improve the quality of their decisions. It is noted that the proposed approach is not only applicable to soccer player selection: it can also be used in other multi-player sports. One suggestion for future research is to embed imprecise or ambiguous judgments into the decision-making process. Finally, a decision support system that uses the proposed solution approach should be developed for general use.

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