

Dynamic Bidding Strategy for Players Auction in IPL

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Abstract. Players' auctions are not new phenomena in the world of sports. However, in the game of cricket auctioning of players was first time used in Indian Premier League (IPL). In IPL, the bidding process was dynamic in nature. No fixed plan worked as franchises had to respond and realign their strategy after each bid by taking into account whether the bid went in their favor or not. It was a phenomenon which was probably not understood much by some franchises. In this paper, we formulate an integer programming model for the efficient bidding strategy for the franchises. This model has been implemented in spreadsheet which helps in taking bidding decisions in real time and overcome winner's curse which is typically associated with normal bidding processes.

Keywords: modeling in sports, bidding, practical relevance, optimization.

1. Introduction

American sports, most particularly baseball and football, have always been characterized by some degree of mathematical analysis. In contrast, the originally English game of cricket has not been subjected to the same degree of mathematical analysis. Traditional versions of cricket are classified based on the number of days they are played. Accordingly there are different versions; test cricket which is played between two countries over a duration of 5 days, one day international cricket played between two international teams where each team normally gets a chance to play a maximum of 50 overs, first class matches are played between domestic teams and between an international visiting team and domestic team for a duration of 3 or 4 days. During the last fifty years game of cricket has seen several changes and all these changes were directed to make this game more popular among the masses and to expand the reach of cricket to non cricket playing nations. However, the most significant change came in response to the declining popularity of test cricket. This was the One Day International (ODI) or limited-overs format of the game that became popular in the 1970s and is now a regular part of the cricket schedule. Twenty20 (T20) is the latest innovation in the game and is even shorter version than ODI cricket. The total duration of the T20 game is about 3 hours, and each team gets to play a maximum of 20 overs. First international T20 match was played between Australia and England on 17th February, 2005. A revolution the way cricket is played across the world came by the introduction of Indian Premier League (IPL), a T20 tournament. For the first time in the history of cricket, IPL introduced the concept of auctioning the cricketers. This idea of auction for the cricketers motivates us to write this paper. There have been some academic studies by the researchers with respect to the game of cricket. Crowe and Middeldorp [5] and Chedzoy [2] investigate the impact of umpiring decisions in test match cricket. Specifically, Crowe and Middeldorp[5] conducted a comparison of leg-before-wicket decision rates between Australia and their visiting teams played in Australia over the period 1977-1994, while Chedzoy[2] analyses the effect of umpiring errors. Brooks et al.[1] analyses the prediction of test cricket outcomes using an ordered response model.

One-day cricket has also received some attention in the literature and represents a good illustration of the mathematical approaches to the analyses of sport. For example, Clarke [3] employs a dynamic programming approach to analyze optimal scoring rates and Johnson et al. [9] using the same methodology, assess player's performance. Duckworth and Lewis [6] presented a method for resetting the target for interrupted one-day matches-a method that currently is being applied to all one-day internationals. Since T20 format is very new so it has not been studied by researches much. However, very recently Karnik [10] estimated the value of

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cricketer, available for auction in IPL 2008 tournament, using hedonic price models. Other aspects of cricket have also been investigated in the literature. For example, Clarke and Norman [4] applied a dynamic programming approach to the issue of protecting the weaker batsman.

In IPL the bidding process for buying the cricketers was dynamic in nature. No fixed plan would have worked as franchises had to respond and realign their strategy after each bid by taking into account whether the bid went in their favor or not. It was a phenomenon which was probably not understood much by some franchises. In this paper, we formulate an integer programming model for the efficient bidding strategy for the franchises in IPL. This model has been implemented in MS Excel which helps in taking bidding decisions in real time and overcome winner's curse which is typically associated with normal bidding processes.

This paper is organized as follows. Brief introduction about IPL and rules of auction for cricketers are given in Section 2. Details related to the data used and assessment of players eligible for auction is given in Section 3. Section 4, describes the integer programming model used to calculate the optimal price of a player. In Section 5, we give the MS-Excel based implementation of the model formulated in Section 4. Section 6, contains a summary, some conclusions and suggestions for future research.

2. IPL and rules of auction

In 2008, the Board of Control for Cricket in India (BCCI) launched the Indian Premier League (IPL) which brought a revolutionary change in the way cricket is played and managed around the world. The league is based on a franchise model. The franchise came from high net worth individuals/ corporate houses previously unconnected with cricket, testifying to the sport's growing profile as a blue chip investment in India. Among the successful bidders were the Bollywood's top stars Shah Rukh Khan and Preity Zinta, a Hyderabad based newspaper group, a UK based media rights company and the regular players, Reliance industries- owned by Mukesh Ambani, one of India's richest man and Vijaya Mallyaa, who also owns a formula one team. The failed bidders included Deutsche bank and construction major DLF.

The IPL was always in the news since the day of its inception for one reason or the other but the media hype really reached its peak when IPL announced the first ever players' auction in which all the 8 franchises participated and bided for 77 odd Indian and Foreign players.

IPL announced that they had already contracted with leading players across various cricketing nations (including Indian international players) to play in the IPL. All arrangements and clearances from their respective Boards had already been obtained. These players would be made available to play for any of the franchises, based on a player auction which had been fixed to take place at BCCI's office in Mumbai on Feb 20, 2008. It was expected to be a full day affair, with the media in full attendance and live coverage of the proceedings by some TV channels. The rules of the auction [7] for players auction in IPL were as follows:

- The Auction will be an open auction with each player being individually presented for auction. The maker of the highest bid accepted by the auctioneer shall be the buyer at that price.
- Each player has an annual "base player fee". The base player fee will be the fee at which the bidding for that player starts.
- Each Franchise has a total "purse" of up to \$5m that it can spend in the Auction for players for 2008. Franchises will not be able to make a bid for a player that would take them beyond this total purse. (Salaries payable for other Indian, State and catchment area players, who become part of the squad, would be outside of this total purse).
- Players in the Auction will be arranged into "sets" according to their base player fee, their cricketing specialty and their expected availability for the 2008 IPL season.
- In advance of the Auction, Franchises will be issued with a list of the players that will be auctioned, the composition of the sets and the order in which the sets will be auctioned.
- Within the sets, the order that players will be presented for auction will be determined by a random draw that will take place in the Auction room.
- Each player will be the subject of an open auction with the auctioneer controlling the process. Bidders will raise a paddle to indicate a bid (only one official bidder per Franchise). Each bid will represent the player fee per season to be paid by the Franchise to the player for each of the seasons 2008, 2009 and 2010, ignoring any periods of unavailability. Once made, no bid may be withdrawn.

- Following the conclusion of each set, there will be a break to allow Franchises time to re-evaluate their tactics.
- Players for whom no bids are received when they are initially presented for auction will be placed in a final set and will be re-presented for auction once all of the initial sets have been concluded.

3. Data and assessment of a player

Due to less number (less than 100 in all) of international 20-20 cricket matches before 2008 player auction and the traditional 50 overs ODI being the closest surrogate, players performance data in the ODIs has been considered for the strategy formulation and cricketers assessment. Specifically, the following data [8] for each of the 77 players that participated in the auction is considered in the analysis:

- Number of matches and innings played.
- Number of total runs scored.
- Batting average.
- Average runs scored per 100 balls.
- Number of half centuries.
- Number of centuries.
- Number of catches taken.
- Number of stumping.
- Number of wickets taken.
- Average number of balls taken per wicket taken.
- Average number of runs given per over.
- Player's speciality (Bowler/ Batsman/ All rounder).
- Age of the player.
- Nationality.
- Whether the player has previously captained his international team.
- Base Auction fees.
- Actual Auction price.

In addition to above, subjective rating of the players based on extensive collation of news, cricketing panel discussions, cricketing sense and subjective analysis has been used to quantify a player's fielding and marketing potential.

3.1. Quantification of players utility to the team

Each of the 77 players have been evaluated on 4 criteria – Batting ability, Bowling ability, fielding ability and Miscellaneous (including Age, Leadership potential and Marketing potential).

[1] Batting ability

Only those players have been considered for the batting potential that have scored at least 200 runs in ODIs. This is because a threshold level is required for a player to evaluate his ability. For example, a player like Joginder Sharma from India has scored his ODI runs at an amazing strike rate of 116.7 runs/ 100 balls. However, since in totality he has scored only 35 runs in International cricket, therefore we cannot arrive at a conclusion for sure that he is a very attacking batsman. Following are the parameters that have been used for evaluation of a player's batting ability:

- *Batting strike rate (average runs scored per 100 balls)* – This indicates the aggressive nature of a player's batting ability. Since, T20 cricket consists only of 20 overs per side; the value of the players who can score runs faster is much more as compared to more traditional test cricket and ODI cricket.
- *Batting average (average runs scored per innings)* – This indicates the consistent nature of a player's batting ability. Aggressive play is ineffective if it cannot be performed in a consistent manner. For example, a player scoring 10 runs at a strike rate of 200 runs/ 100 balls is probably of little use to a team as compared to a player who scores 50 runs at a strike rate of 100 runs/ 100 balls.
- *Number of half centuries and centuries* – This indicates the ability of a player to win matches on his own for his team and be the player who can play the central role in teams batting strategy. For example, players like MS Dhoni and Sachin Tendulkar from India are the kind of players every team

would like to have because when in the middle, these are backbone of a team's batting line up and around which the whole batting of the team can revolve.

The function used to quantify the batting potential of a player is given as follows:

$$\text{Batting Score} = 0.5 \times B_A^2 + 0.5 \times B_{SR}^{1.5} + 0.8 \times C_T + 0.3 \times H_{CT}$$

where,

B_A : Batting Average,

B_{SR} : Batting Strike Rate,

C_T : Number of Centuries,

H_{CT} : Number of Half Centuries.

A square function is used for batting average as the range in batting averages is usually seen to be pretty less. For a proper batsman of an international team, this number is usually in the range of 35-45. The square function helps in magnifying this difference. On the other hand, in case of batting strike rate, the usual range for international batsmen is 65-100 runs / 100 balls. Hence, power of 1.5 is used for quantifying the aggressive nature of a player's batting ability. Same weight is given to both average and strike rate and in absolute terms, strike rate has usually higher value than average and hence, this helps in giving more importance to the aggressive batting ability of a player in evaluation of his overall batting ability. This is in sync with the nature of the T20 cricket. More importance is given to centuries scored by a player as compared to half centuries. Here a linear function is used as there is an overlap between batting average and number of centuries and half centuries scored by a player.

The batting score is an absolute number. Since it is only one of the four criteria that are being considered to evaluate a player's utility, this score is normalized by dividing this number by the median batting score of the 77 players being considered for the strategy formulation. It should be noted that while considering the median, batting scores of all players including those who score 0 on this parameter have been included in the analysis. This is because unlike bowling, every player can contribute to his team with his batting abilities. For example: Suresh Raina has scored 1558 runs in ODI at an average of 35.4 and strike rate of 86.02. He has scored two centuries and 10 half centuries. Hence his batting score is

$$= 0.5 \times (35.4)^2 + 0.5 \times (86.02)^{1.5} + 0.8 \times 2 + 0.3 \times 10 = 1030.$$

The median of the batting score of the 77 players considered for the analysis comes out to be 689. Hence, the normalized batting score of Suresh Raina is $1030/689 = 149.55$.

Bowling ability

Only those players have been considered for the bowling potential that have taken at least 20 wickets in ODIs. This is because as in the case of evaluation of batting potential of a player, threshold level is required for a player to evaluate his ability. For example, a player like Mohammad Yusuf from Pakistan has taken his ODI wickets at an amazing strike rate of 2 balls/ wicket and at an impressive economy of 3 runs/ over. However, since in totality he has taken only 1 wicket in International cricket, therefore we cannot arrive at a conclusion for sure that his utility as a bowler is very high. The following are the parameters that have been used for evaluation of a player's bowling ability:

- *Bowling strike rate (average balls bowled per wicket)* – This indicates the aggressive nature of a player's bowling ability. Since, T20 cricket is a shorter version of cricket; it is very rare that a team is able to rebuild its inning in case of an early damage in the form of wickets. It is not like test cricket where you can come back into the match from any position. Hence, the wicket taking abilities of a bowler plays a very important role.
- *Economy (average runs given per over)* – This indicates the restrictive nature of a player's bowling ability. In T20 cricket, batsmen are always looking for hitting the bowlers out of the ground. However, sometimes with good bowling, even when opposition has wickets in hand, it is possible to restrict the opposition to a reasonable score by economical bowling. Players who can bowl well in the death overs and bowl yorkers at will are specially valued.

The function used to quantify the bowling potential of a player is as follows:

$$\text{Bowling Score} = 800 - E_{CON}^{3.5} - S_R^{1.5}$$

where,

E_{CON} : Bowler's Economy Rate,

S_R : Bowlers' Strike Rate.

Bowling score will be a decreasing function of the two parameters as lower the bowling strike rate and lower the economy, better the bowler. A power of 3.5 was used for the parameter economy while a power of 1.5 was used for strike rate as in absolute terms, economy is a much lower number than strike rate. We usually see that for international bowlers, economy is in range of 4-5 runs per over whereas strike rate is in the range of 30- 40 balls/ wicket. Hence, a power of 3.5 magnifies the difference between bowler's restrictive bowling ability and helps in better quantification

The bowling score is an absolute number. Since it is only one of the four criteria that are being considered to evaluate a player's utility, this score is normalized by dividing this number by the median bating score of the players scoring above zero on this criteria amongst the 77 players being considered in the analysis. This is because not every player is required to contribute in the team as a bowler.

For instance, Harbhajan Singh has taken 207 wickets in ODI at an economy of 4.22 and strike rate of 46.7. Hence his bowling score is

$$800 - (4.22)^{3.5} + (46.7)^{1.5} = 326.$$

The median of the bowling score of the players with above zero score on the bowling ability criteria considered for the analysis comes out to be 307. Hence, the normalized bowling score of Harbhajan Singh is quantified as $326/307 = 106.44$.

Fielding ability

Fielding score has been calculated separately for wicket keepers and other players. This is because wicket keepers by virtue of their fielding position play a much more crucial role in terms of taking catches and executing stumping. Hence, we observe a skewed data in terms of their catches and stumping affected by them as compared to other players. The parameters that have been used for evaluation of a player's fielding ability are as follows:

- *Catches taken per match* – This is actually the only data which is easily available and which gives some directional insight into the fielding abilities of a player. Only those players who have played more than 15 ODIs have been considered for this parameter. This is because players with less than 15 ODIs may have skewed data on this parameter. For example, a player who has taken 75 catches in 100 matches with catches/ match ratio of 0.75 has much more authenticity in terms of validity as compared to a player who has taken 3 catches in 4 matches. The criteria of 15 matches help in discarding such scenarios.
- *Fielding rating* – Catches per match cannot be the sole criteria which can explain a player's fielding potential. This can give us a skewed scenario as there are certain natural specific fielding positions like slips, etc where players will get more opportunities to take catches. For example, there may be a scenario where a player who often fields at slips has taken 100 catches. But at the same time, these catches had been taken at the cost of dropping 50 catches. This is a soft issue and there are data limitations to quantify this aspect. Hence, we have used a 0-10 scale to rate a player's fielding ability based on extensive collation of news, cricketing panel discussions, cricketing sense and subjective analysis.

The function used to quantify the fielding potential of a player is as follows:

$$\text{Fielding Score} = (C_{PM} \times 20)^2 + F_R^2$$

where,

C_{PM} : Catches per Match,

F_R : Fielding Rating.

Fielding score is an increasing function of both the parameters, catches per match and fielding rating. The coefficient of 20 is used in order to give similar weight to both the parameters. Typically, catches per match for a player is in the range of 0.2-0.5. Hence, coefficient of 20 brings it at par with the 0-10 scale fielding rating. In case of wicket keepers, since the catches per match are usually greater than 1, this function gives more weight to catches per match effectively. This is justified as wicket keepers have a more specific role in the fielding department and more often than not, get ample opportunities to execute dismissals in the form of catches and stumping.

The fielding score is an absolute number. Since it is only one of the four criteria that are being

considered to evaluate a player's utility, this score is normalized by dividing this number by the median fielding score of the players separately in wicket keeping and non wicket keeping categories. This is because not every player is required to contribute in the team as a bowler. For instance, Suresh Raina has taken 29 catches in 65 ODIs and has a fielding rating of 9. Hence his fielding score is $(20 \times 29/65)^2 + 9^2 = 161$.

The median of the fielding score of the players which are not wicket keepers considered for the analysis comes out to be 85. Hence, the normalized fielding score of Suresh Raina is quantified as $161/85 = 188.54$.

[2] Miscellaneous ability

This basically consists of three parameters by which a player can contribute to his franchise in non cricketing ways. The parameters that have been used for evaluation of a player's miscellaneous ability are as follows:

- *Leadership ability* – 20-20 cricket is a very dynamic form of cricket where no one strategy can work. A team has more chances of winning if it goes into the game with multiple strategies considering different scenarios. Equally important is the execution of the strategies which is the job of the captain of the team. The captain should be a player who not only is able to contribute in the formulation of the strategies but also someone who can react and adapt appropriately to various situations arising in the game. In international cricket, any player who has been considered to captain his team can be assumed to be having the leadership capabilities.
- *Marketing Potential* – IPL is as much about earning big money as about playing competitive cricket. From a marketing perspective and earning money through sponsorship, merchandising, etc, only winning matches alone will not be enough. For example, Indian cricket team is not always considered the best in the world but still there is a huge fan following. This helps BCCI earn big money from broadcasting rights, team sponsorship, etc. Hence, a franchise would require players which can help them gain loyalty of fans and target specific segments of the cricket fans. Since this is an Indian based league, a franchise having more Indian international players will benefit more. Also, international players with worldwide reputation would have a good marketing potential. From quantification point of view, like fielding ability this is again a soft issue and there are data limitations to quantify this aspect. Hence, we have used a 0-10 scale to rate a player's marketing potential based on extensive collation of news, cricketing panel discussions, cricketing sense and subjective analysis.
- *Age* – 20-20 cricket has often been regarded as young man's game. Since the nature of the game is so fast, the level of fitness and agility required is also pretty high. Hence, naturally there is a preference for younger players. Also, as per the IPL rules, all players need to be offered 3 year contracts. Hence, with a young player there is more visibility with respect his relationship with the franchise. In case of older players, they might be of value to the team for 1 or 2 years but may simply end up as a liability later on. Therefore, a premium is attached with the age of the players.

The function used to quantify the miscellaneous potential of a player is as follows:

$$\text{Miscellaneous Score} = L_S + A_S + M_P^3$$

where,

L_S : Leadership Score,

A_S : Age Score,

M_P : Marketing Potential.

Here leadership score is 700 for a player who has captained his respective international team in the past.

A player gets:

- 700 points; if age is less than 30 years.
- 0 points; if age is more than 30 years but less than 35 years.
- -500 points; if age is more than 35 years.

The cubic function has been used for the marketing potential to amplify the differences between the players on this parameter. Overall, the function gives more weight to marketing potential for a player who scores high on this parameter as the impact of this parameter is perceived to be higher than the other two. Players who are more than 35 years old are perceived more as a liability from agility and contractual constraints point of view and hence have been assigned negative points. For instance, Suresh Raina has never

captained Indian ODI team, is 22 years old and has a marketing potential of 9. Hence his miscellaneous score is

$$0 + 700 + (9)^3 = 1429.$$

The median of the miscellaneous score of the players considered for the analysis comes out to be 727. Hence, the normalized miscellaneous score of Suresh Raina is quantified as $1429/727 = 196.56$.

Overall utility

The overall utility of a player is the weighted average of the player's utility as a batsman, bowler, and fielder to the team along with his miscellaneous contributions. The weights that have been assigned to different skills of a player are as follows:

- Batting : 0.35
- Bowling: 0.30
- Fielding : 0.15
- Miscellaneous: 0.20.

The function used to quantify overall score of a player is as follows:

$$\begin{aligned} \text{Net Score} &= 0.35 \times \text{Normalized Batting Score} + 0.30 \times \text{Normalized Bowling Score} + 0.15 \\ &\times \text{Normalized Fielding Score} + 0.20 \times \text{Normalized Miscellaneous Score; for a player with Normalized Bowling Score} \\ &\text{greater than equal to 100.} \\ \text{Net Score} &- 0.35 \times \text{Normalized Batting Score} + 0.30 \times (0.5 \times \text{Normalized Bowling Score}) \\ &+ 0.15 \times \text{Normalized Fielding Score} + 0.20 \times \text{Normalized Miscellaneous Score; for a player with Normalized Bowling Score} \\ &\text{less than 100.} \end{aligned}$$

More weight has been given to batting and bowling as these forms the core abilities required for the game. A player excelling in at least one of these is a non negotiable pre requisite required from anyone who aspires to play the game at a professional level.

Further, between batting and bowing, more weight is given to batting as compared to bowling as every player can contribute to the team as a batsman but not everyone is required to contribute as the bowler. Further, a player, who can bowl but is a below average bowler (defined by the median score), adds lesser value to the team as more often than not his services as a bowler won't be utilised by the team. Hence, a factor of 0.5 is multiplied with the bowling ability of a player who scores below average in the bowling ability criteria.

Fielding has been given relatively lesser weight as compared to miscellaneous because a player's value in terms of his leadership ability and marketing potential are perceived to be of more important as compared to the fielding ability. Moreover, miscellaneous ability also takes into account the age of a player; hence in an indirect way it takes into consideration the agility of a player also which introduces some kind of overlap between the two criteria. Therefore, the lower weight to the fielding ability criteria is justified.

For instance, Suresh Raina scores 149.55 on batting criteria, 0 on bowling criteria, 188.54 on fielding criteria and 196.56 on miscellaneous criteria. Hence his overall net score is equal to

$$0.35 \times (149.55) + 0.30 \times (0.5 \times 0) + 0.15 \times (188.54) + 0.20 \times (196.56) = 120.$$

4. Model formulation

The optimum team would be one which has the best possible players with a balanced composition in terms of specialized talents of constituting players and would not cost more than the allocated budget. The integer programming model explained in the following passages has been constructed to achieve precisely that objective. In order to achieve a balance in composition of the squad, we have introduced several constraints apart from the budget constraint. We shall explain how the model automatically keeps adjusting for various contingencies such as failed bids, successful bids, scarcity of players remaining in the auction process and budget surpluses. First we introduce the following notations that we have used in this study:

- O : Index set of all players in the auction.
 O_b : Index set of Batsmen.
 O_o : Index set of Bowlers.
 O_{of} : Index set of Fast Bowlers.
 O_{os} : Index set of Spin Bowlers.
 O_r : Index set of All Rounders.
 O_w : Index set of Wicket Keepers.
 O_c : Index set of Captain Level Players.
 O_N : Index set of players of Indian Nationality.
 NS_i : Net score of player i .
 x_i : Binary decision variable for selection status of a player i in auction (1 if selected, 0 otherwise).
 C : Budget left at any stage.
 BP_i : Base auction price for player i .
 AP_i : Actual auction price for player i .
 U_i : Adjusted utility of player i .
 U_{b_i} : Base utility of player i .
 F_{u_i} : Utility factor for player i .
 A_i : Binary constant for availability status in bidding (1 if available, 0 otherwise).

4.1. Objective function

The net score calculated in the previous section is used as a quantitative definition of the player's relative ability. In order to achieve the best possible squad composition, we define our objective function as "Maximization of sum of net scores of players constituting the squad". Thus, our objective function is

$$\text{Maximize } \sum_{i \in O} NS_i x_i$$

4.2. Budget constraint

This is clearly one of the most critical constraint in squad selection. We have taken the base price as an ex ante auction price indicator. With this, we defined our budget constraint as twice the total base price of players selected in the squad. Hence, at any stage,

$$2 \sum_{i \in O} BP_i x_i \leq C$$

where,

$$C = 5,000,000 - \sum_{i \in O} AP_i x_i$$

The factor of 2 has been taken considering the average of the difference between the actual auction prices and base prices for the players which materialized during the first such auction. The average of this difference was approximately 270,000 and taking in a squad of 9 players, the difference which we are looking at is around 2,500,000 from the total base price. Hence, given a budget of 5,000,000; if we average out the fluctuations we should have a factor of 5/2.5 (=2).

Hence, the budget constraint keeps getting updated with every successful bid as per the actual price paid for the player in that round.

For instance, if for Chris Gayle, the maximum bid amount as per the model comes out to be 1,000,000 but during the auction, the franchise's bid for 900,000 was successful then, for the next iteration,

$$C = 5,000,000 - 900,000 = 4,100,000.$$

4.3. Constraints

The following initial constraints are imposed to get a best possible combination of players with different cricketing skills:

$\sum_{i \in O} x_i \leq 9$ (Number of selected players should be less than 9 so as to focus on quality rather than quantity),

$$\sum_{i \in O_b} x_i \geq 2 \text{ (Selected squad should have at least 2 batsmen),}$$

$$\sum_{i \in O_o} x_i \geq 2 \text{ (Selected squad should have at least 2 bowlers),}$$

$$\sum_{i \in O_r} x_i \geq 2 \text{ (Selected squad should have at least 2 all-rounders),}$$

$$\sum_{i \in O_{os}} x_i \geq 1 \text{ (Selected squad should have at least 1 spin bowler),}$$

$$\sum_{i \in O_{of}} x_i \geq 1 \text{ (Selected squad should have at least 1 fast bowler),}$$

$$\sum_{i \in O_w} x_i \geq 1 \text{ (Selected squad should have at least 1 wicketkeeper),}$$

$$\sum_{i \in O_c} x_i \geq 1 \text{ (Selected squad should have at least 1 captain level player),}$$

$$\sum_{i \in O_i} x_i \geq 4 \text{ (Selected squad should have at least 4 Indian players).}$$

These constraints can vary based on a particular team's requirement and have been taken here only for demonstration purpose.

One player can satisfy more than a single requirement noted above. For instance, Chris Gayle is an all rounder, spin bowler as well as a captain level player. Our categorization of players into bowlers, batsmen, wicket keeper and all rounder reflects their skills as a specialist in that area. Specialist bowlers and all-rounders can be further sub-categorized as spin or fast bowlers. Thus the cricketing requirement of having specialist bowlers in the team irrespective of presence of all-rounders who can bowl is reflected in our categorization and the use of constraints. These initial constraints are valid for the opening of the bidding process. As the bidding progresses the model has been designed to modify the constraints as per changes in:

- Remaining number of players required to complete the squad.
- Remaining number of players of particular specialization required to complete the squad.
- The pool of players remaining under auction.
- Specialization of the players remaining under auction.

These rules have been designed into the model to incorporate all plausible scenarios which could develop once the bidding commences. They also minimize possibility of human error while doing quick optimizations during a bidding process.

As the bidding continues and different franchises win or loose in their bids for each of the players, the pool of players remaining under bidding will keep getting smaller and simultaneously, the remaining players needed to complete the squad also decreases. Further, as the actual budget left for next round of bidding changes, the optimum team which could be put together in the remaining budget could also change. The different possible scenarios are discussed in later sections of this paper.

The above optimization model based on binary integer programming problem has already been implemented on MS-Excel and optimal bid price for a player can be obtained in run time. The model adapts to the dynamic nature of the bidding process in the following ways:

The constraint for the total number of players and the specialty-wise player constraint changes with each successful bid. For instance, assuming our first successful bid is for Chris Gayle; whose speciality includes All Rounder, Spin Bowler and Captain Level Player; then the constraints would automatically change as follows:

$$\sum_{i \in O} x_i \leq 9 - 1 = 8,$$

$$\sum_{i \in O_b} x_i \geq 2,$$

$$\sum_{i \in O_o} x_i \geq 2,$$

$$\sum_{i \in O_r} x_i \geq 2,$$

$$\sum_{i \in O_{os}} x_i \geq 1 - 1 = 0,$$

$$\sum_{i \in O_{of}} x_i \geq 1,$$

$$\sum_{i \in O_w} x_i \geq 1,$$

$$\sum_{i \in O_c} x_i \geq 1 - 1 = 0,$$

$$\sum_{i \in O_N} x_i \geq 4$$

If for some reason, we are not able to successfully bid for sufficient number of players in any of the category and the pool of players remaining under auction shrinks to less than our remaining requirement, then the constraints are relaxed to achieve a feasible solution of the optimization problem. For instance, if at any stage, the number of bowlers required is 2 and only 1 bowler remains in the bidding process than the constraint on bowlers is adjusted as follows:

$$\text{Number of bowlers} \geq \text{Minimum (2, bowlers left under auction)} = 1.$$

Further, at this stage the logical result would be to increase the utility of the remaining bowlers for the bidding franchise which is still short of its minimum requirement of bowlers. This should result in a higher bid price for players under this category. This scenario has also been incorporated in our model and is described later in this paper.

4.4. Determining the maximum bid amount

Economics dictates that the price of any player should be capped by his utility for the team. Utility for a cricket squad would be an increasing function of the players overall skill level and should be influenced by the relative scarcity of players in his particular category. We have defined the utility U_i of player i as follows:

$$U_i = F_{u_i} \times NS_i^3,$$

where F_{u_i} is player specific utility factor, which is designed to magnify the base level utility of a player in situations where the pool of available players of his particular category shrinks beyond a threshold level. The threshold level is taken as twice of the remaining number of players in any particular category required to meet the constraints. The construction of utility as a cubic function of net score is designed to magnify the differences in net score in deriving the utility of the player. For instance, with a net score of 21, spin bowler Romesh Powar's base level utility is $(21)^3 = 9261$. Assuming we require one spin bowler to satisfy our minimum requirement of spinners. Now, as long as more than 2 (twice the minimum requirement of spinners for the franchise) spin bowlers remain in the bidding pool, the utilities used as input in the objective function stay at base levels which is to say that $F_{u_i} = 1$. But if this comfort factor drops to 2 or below, it signals an increased urgency to acquire the minimum requirement in the relevant category. Hence, at this stage, the utility factor for all players of this category remaining in the bidding pool is increased so that $F_{u_i} = 1.3$.

The final utility values thus obtained are used in conjunction with the remaining budget to determine the maximum bid amount for the set of players selected through the team optimization algorithm. This is determined by allocating the budget to the players targeted in the bidding in direct proportion to their utility to the squad.

Hence, $P_{i,\max} = U_i \times C / \sum_{i \in T} U_i$, where, T is the set of players to be targeted during bidding.

4.5. Case of budget surplus

The initial constraint on bidding for not more than 9 players is the squad has been put in place keeping in mind a reasonable number which could be expected to be won in a competitive bidding process. Taking a larger number at the start would lead to budget getting thinly distributed over the set of targeted players which could lead to too many failed bids, similarly a smaller targeted size of squad would result in few good players and / or leftover budget at the end. However, if it so happens that we could acquire our chosen squad without exhausting the budget, then at the end, we will relax this constraint to 10. Since we have already acquired 9 players by now, we will essentially end up bidding for the best available player who could be afforded within the leftover budget.

5. Spreadsheet implementation

At the time when auction starts, the initial optimal set T of targeted players (shown in shadow in the next spreadsheet) for which the bidding should be done as given by the Excel Solver Optimization and their maximum bid price is shown in the following spreadsheet:

Players	Base Price	Net Score	Availability	Successful bid	Max Bid Price (USD)	Actual Bid Price	Nationality	Batsman	All Rounder	Bowler	Spin Bowler	Fast Bowler	Wicket Ke
MS Dhoni	4,00,000	168	1	0	12,04,372	0	1	0	0	0	0	0	0
Chris Gayle	2,50,000	145	1	0	7,73,357	0	0	0	1	0	1	0	0
Graeme Smith	2,50,000	138	1	0	6,74,769	0	0	1	0	0	0	0	0
Michael Hussey	2,50,000	137	1	0	6,63,118	0	0	1	0	0	0	0	0
Shoaib Malik	3,00,000	126	1	0	-	0	0	0	1	0	1	0	0
A B deVilliers	2,00,000	122	1	0	-	0	0	1	0	0	0	0	0
Ricky Ponting	3,25,000	122	1	0	-	0	0	1	0	0	0	0	0
Suresh Raina	1,25,000	120	1	0	4,40,200	0	1	1	0	0	0	0	0
Shaun Pollock	2,00,000	115	1	0	3,88,242	0	0	0	1	0	0	1	0
Andrew Symonds	2,50,000	107	1	0	-	0	0	0	1	0	1	0	0
Shahid Afridi	2,75,000	106	1	0	-	0	0	0	1	0	1	0	0
Jacques Kallis	2,25,000	105	1	0	-	0	0	0	1	0	0	1	0
Harbhajan Singh	2,50,000	105	1	0	2,96,382	0	1	0	0	1	1	0	0
Goutam Gambhir	2,00,000	104	1	0	2,85,359	0	1	1	0	0	0	0	0
Shane Warne	4,50,000	102	1	0	2,74,201	0	0	0	0	1	1	0	0
Rohit Sharma	1,50,000	101	1	0	-	0	1	1	0	0	0	0	0
Ramnaresh Sarwan	2,25,000	101	1	0	-	0	0	1	0	0	0	0	0
Mohammad Kaif	1,25,000	98	1	0	-	0	1	1	0	0	0	0	0
Farveez Maharoof	1,50,000	98	1	0	-	0	0	0	1	0	0	1	0

Fig. 1: Spreadsheet showing initial optimal set of players.

Now when the auction begins, the first player that comes for bidding is Muttiah Muralidaran who is not amongst the optimal set of players. As per the initial optimal solution, we are not interested in bidding for him. Hence, we just remove him from the further analysis and don't participate in his auction.

The next in line is MS Dhoni who is a part of the optimal team. Hence, we participate in his bidding which starts at \$400,000. The corresponding maximum bidding price suggests that we shall not bid in excess

of \$1,204,372 for him. Now there are two scenarios possible here:

Scenario 1 of failed bid

Assuming that some other franchise bids for Dhoni in excess of our maximum bid price. In this case, we lose Dhoni but are saved from the winner's curse. We remove Dhoni from the analysis and rerun the model which gives the following new set of optimal players at this instant:

Players	Base Price	Net Score	Availability	Successful bid	Max Bid Price (USD)	Actual Bid Price	Nationality	Batsman	All Rounder	Bowler	Spin Bowler	Fast Bowler	Wicket Ke
MS Dhoni	4,00,000		0	0	-	-	0	1	0	0	0	0	0
Chris Gayle	2,50,000	145	1	0	9,71,754	-	0	0	0	1	0	1	0
Graeme Smith	2,50,000	138	1	0	8,47,875	-	0	0	1	0	0	0	0
Michael Hussey	2,50,000	137	1	0	8,93,235	-	0	0	1	0	0	0	0
Shoaib Malik	3,00,000	126	1	0	6,39,385	-	0	0	0	1	0	1	0
A J de Villiers	2,00,000	122	1	0	-	-	0	0	1	0	0	0	0
Ricky Ponting	3,25,000	122	1	0	-	-	0	0	1	0	0	0	0
Suresh Raina	1,25,000	120	1	0	5,53,130	-	0	1	1	0	0	0	0
Shaun Pollock	2,00,000	115	1	0	-	-	0	0	0	1	0	0	1
Jacques Kallis	2,25,000	105	1	0	-	-	0	0	0	1	0	0	1
Harbhajan Singh	2,50,000	105	1	0	3,72,416	-	0	1	0	0	1	1	0
Gautam Gambhir	2,00,000	104	1	0	3,58,566	-	0	1	1	0	0	0	0
Shane Warne	4,50,000	102	1	0	-	-	0	0	0	0	1	1	0
Robin Uthappa	2,00,000	97	1	0	-	-	0	1	1	0	0	0	0
Adam Gilchrist	3,00,000	96	1	0	3,01,156	-	0	0	0	0	0	0	0
Brendon McCullum	1,75,000	97	1	0	-	-	0	0	0	0	0	0	0
Chamara Silva	1,00,000	73	1	0	-	-	0	0	1	0	0	0	0
Zaheer Khan	2,00,000	73	1	0	1,22,482	-	0	1	0	0	1	0	1
Ashwell Prince	1,75,000	70	1	0	-	-	0	0	1	0	0	0	0
Kamran Akmal	1,50,000	71	1	0	-	-	0	0	0	0	0	0	0
Mohammad Yousuf	3,30,000	71	1	0	-	-	0	0	1	0	0	0	0

Fig. 2: Spreadsheet showing the new optimal set of targeted players after scenario 1.

Optimization Routine					
Objective (Maximize)	1045.71				
Constraints	Optimize	Limit	Type	Availability	Availability/Limit
No. of Players	9	9	Max	76	8.44
Batsman	4	2	Min	26	13.00
Bowlers	2	2	Min	25	12.50
All Rounders	2	2	Min	17	8.50
Spin Bowlers	3	1	Min	16	16.00
Fast Bowlers	1	1	Min	26	26.00
Wkt Keepers	1	1	Min	8	8.00
Captain Level Players	4	1	Min	17	17.00
Nationality	4	4	Min	24	6.00
Budget	4250000	5000000	Max		
Size of Squad Targeted		9			

Fig. 3: Spreadsheet showing the changes in the optimization model after scenario 1.

We now participate in the auction with the aim of winning bids for the above optimal set of players.

Scenario 2 of successful bid

We keep on increasing our bid for Dhoni and ultimately win him at \$1,200,000. Accordingly the budget constraint changes for the subsequent bidding process as now budget of only \$ 3,800,000 is left. The base price of Dhoni is \$400,000 and hence if Dhoni was bought at, $2 \times 400,000 = 800,000$ the optimal team would

have remained same since the budget constraint is $2 \times \sum_{i=1}^n BP_i \times x_i \leq C$.

In this case, since 1,200,000 is greater than 800,000, budget shrinks for the other players. Hence, the

optimal team will change as fewer budgets is available now than what was considered earlier. We remove Dhoni from the analysis and rerun the model which gives the following new set of optimal players at this instant:

Players	Base Price	Net Score	Availability	Successful bid	Max Bid Price (USD)	Actual Bid Price	Nationality	Batsman	AllRounder	Bowler	Spin Bowler	Fast Bowler	Wicket Ke
MS Dhoni	4,00,000		0	1	-	1200000	1	0	0	0	0	0	0
Chris Gayle	2,50,000	145	1	0	7,49,471	0	0	0	1	0	1	0	0
Graeme Smith	2,50,000	138	1	0	6,53,928	0	0	1	0	0	0	0	0
Michael Hussey	2,50,000	137	1	0	6,42,637	0	0	1	0	0	0	0	0
Shoaib Malik	3,00,000	126	1	0	4,93,129	0	0	0	1	0	1	0	0
A B de Villiers	2,00,000	122	1	0	4,52,537	0	0	1	0	0	0	0	0
Virky Pranting	3,75,000	177	1	0	-	0	0	1	0	0	0	0	0
Suresh Raina	1,25,000	120	1	0	4,26,604	0	1	1	0	0	0	0	0
Shaun Pollock	2,00,000	115	1	0	-	0	0	0	1	0	0	0	1
Jacques Kallis	2,25,000	105	1	0	-	0	0	0	1	0	0	0	1
Harbhajan Singh	2,50,000	105	1	0	2,87,228	0	1	0	0	1	1	0	0
Gautam Gambhir	2,00,000	104	1	0	-	0	1	1	0	0	0	0	0
Chamara Silva	1,00,000	73	1	0	-	0	0	1	0	0	0	0	0
Zaheer Khan	2,00,000	73	1	0	94,465	0	1	0	0	1	0	0	1
Ashwell Prince	1,75,000	70	1	0	-	0	0	1	0	0	0	0	0
Kamran Akmal	1,50,000	71	1	0	-	0	0	0	0	0	0	0	0
Mohammad Yousuf	3,30,000	71	1	0	-	0	0	1	0	0	0	0	0
Chaminda Vaas	2,00,000	70	1	0	-	0	0	0	0	1	0	0	1
Lasith Malinga	2,00,000	70	1	0	-	0	0	0	0	1	0	0	1

Fig. 4: Spreadsheet showing the optimal set of players after scenario 2.

Optimization Routine				
Objective (Maximize)		966.29		
Constraints	Optimize	Limit	Type	Availability / Availability/Limit
No. of Players	8	8	Max	76 / 9.50
Batsman	4	2	Min	26 / 13.00
Bowlers	2	2	Min	25 / 12.50
All Rounders	2	2	Min	17 / 8.50
Spin Bowlers	3	1	Min	16 / 16.00
Fast Bowlers	1	1	Min	26 / 26.00
Wkt Keepers	0	0	Min	8
Captain Level Players	3	0	Min	17
Nationality	3	3	Min	24 / 8.00
Budget	3650000	3800000	Max	

Size of Squad Targeted 9

Fig. 5: Spreadsheet showing the changes in optimization model after scenario 2.

Above 8 players along with Dhoni form the optimal team at this instant. We now participate in the auction with the aim of winning bids for the above optimal set of players. We continue bidding till the auction ends or the budget is exhausted or we get the desired set of players whichever is earlier.

6. Conclusion

In this paper, we have formulated an integer programming model which helps IPL franchise to take efficient bidding decisions in real time during the auction. MS-Excel based implemented version of the model developed in this paper may be used by the participated franchises to formulate its bidding strategy with an automated dynamic bidding strategy. Spreadsheet based implemented model developed here is

capable of incorporating different other possible scenarios such as more weight can be assigned to most recent form of a cricketer (say during last six months) in evaluation of the net score. As a direction for future research there may be a scope to develop a game theoretic bidding strategy model that can take into account the anticipated bidding of the competitor.

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