

Optimization Project Report - Selection of Optimal IPL Teams

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1 Problem statement

Our goal is to treat the IPL auction as an optimization problem. We aim to maximize the overall performance of the team within a given budget. We provide two outputs:

1. The best possible Royal Challengers Bangalore (RCB) team, considering retained players.
2. The best possible team when starting from scratch, assuming there are no retained players.

2 Solution

1. Player performance

To quantify the performance of players in the team, we implement the method in this research paper: [source](#)

We used the complete IPL ball-by-ball score data to calculate player performance: [source](#)

The method has been summarized below:

Performance Index for Batsman (PIB) The performance of a batsman is assessed based on the "quality" of the bowlers faced. The performance index for batsman i against bowler j is given by:

$$PI_{B_{ij}} = \frac{\text{Batting Average of Batsman i against Bowler j}}{\text{Career Bowling Average of Bowler j}} \times 100$$

Total performance index of a batsman is the sum of the individual $PI_{B_{ij}}$:

$$TPI_{B_i} = \sum PI_{B_{ij}}$$

Average performance index of a batsman API_{B_i} is:

$$API_{B_i} = \frac{TPI_{B_i}}{\text{Number of Bowlers Faced}}$$

Example:

Assume Batsman A faces 5 bowlers. The calculated $PI_{B_{ij}}$ values for the bowlers result in:

$$TPI_B = 827.801$$

Thus, the average performance index of Batsman A is:

$$API_B = \frac{827.801}{5} = 165.5602$$

Performance Index for Bowler (PIBo) The performance of a bowler is based on the "quality" of the batsmen dismissed. The performance index for bowler i against batsman j is:

$$PI_{BO_{ij}} = \frac{\text{Career Batting Average of Batsman j}}{\text{Bowling Average of Bowler i against Batsman j}} \times 100$$

Total performance index of a bowler is the sum of the individual $PI_{BO_{ij}}$:

$$TPI_{BO_i} = \sum PI_{BO_{ij}}$$

Average performance index of a bowler API_{BO_i} is:

$$API_{BO_i} = \frac{TPI_{BO_i}}{\text{Number of Batsmen Bowled Against}}$$

Example:

Assume Bowler B bowls against 5 batsmen. The calculated $PI_{BO_{ij}}$ values result in:

$$TPI_{BO} = 777.5964$$

Thus, the average performance index of Bowler B is:

$$API_{BO} = \frac{777.5964}{5} = 155.5193$$

The performance index effectively quantifies the "quality" of runs scored by a batsman and wickets taken by a bowler. Runs against high-quality bowlers and wickets of top-order batsmen carry more credit.

Players with limited participation are excluded from consideration due to insufficient data to reliably assess their performance metrics.

We calculate the batting and bowling performance index for each of the players. The total batting and bowling performance of a player is considered to be the performance index of the player.

2. Auction Data

We have used auction data for the year 2022, assuming the auction prices to be constant.

We obtained the auction prices of the sold players from source. We obtained the data of the unsold players from source. These two datasets were merged.

We obtained the RCB team players of the year 2021 from source, to be used in the retained players calculation.

The player performances calculated earlier were merged with this data.

3. Rules

The following IPL auction rules were considered while optimizing team composition:

- (a) Team size: Must include 18–25 players.
- (b) Budget: Total expenditure cannot exceed Rs. 90 crore.
- (c) Retention: Teams can retain up to 6 players from the previous season. Up to 5 capped players can be retained, and up to 2 uncapped players can be retained. For the uncapped players, Rs 4 crore is the fixed salary. Retention costs for the capped players are as follows:
 - 1st Retention: Rs. 18 crore
 - 2nd Retention: Rs. 14 crore
 - 3rd Retention: Rs. 11 crore
 - 4th Retention: Rs. 18 crore
 - 5th Retention: Rs. 14 crore
- (d) Overseas player limit: A maximum of 8 overseas players is allowed.

Apart from the rules set in the IPL auction, we ensure that the team must have a balanced composition of batsmen, bowlers, and all-rounders. It should avoid scenarios where the team is heavily skewed towards exceptional batsmen with poor bowling options (or vice-versa).

We aim to create a team that optimizes performance metrics while maintaining feasibility under IPL auction rules.

3 Optimization Problem Formulation

We model the IPL auction optimization problem with the following objective function and constraints.

3.1 Variables

- x_i : Binary variable, 1 if player i from auction pool is chosen, 0 otherwise.
- r_i : Binary variable, 1 if player i from the previous season's team is retained, 0 otherwise.
- y_{ix} : Binary variable, 1 if player i from the auction pool is an overseas player, 0 otherwise.
- y_{ir} : Binary variable, 1 if player i from previous game season is an overseas player, 0 otherwise.
- z_k : Binary variable, 1 if k players are retained, 0 otherwise.

3.2 Parameters

- $bowl_{ix}$: Bowling performance index of player i from the auction pool.
- bat_{ix} : Batting performance index of player i from the auction pool.
- $bowl_{ir}$: Bowling performance index of player i from previous game season.
- bat_{ir} : Batting performance index of player i from previous game season.
- b_i : Cost of player i in the auction.
- c_k : Cost of retaining k capped players:

$$c_1 = 18 \text{ crore,}$$

$$c_2 = 32 \text{ crore,}$$

$$c_3 = 43 \text{ crore,}$$

$$c_4 = 61 \text{ crore,}$$

$$c_5 = 75 \text{ crore,}$$

- Budget: Total budget for building the team = 90 crore.

- C: Set of capped players
- U: Set of uncapped players
- c: Cost of retaining an uncapped player = 4 crore.

3.3 Objective Function

$$\begin{aligned} \text{Maximize } & \sum_i (bowl_{ix} + bat_{ix}) \cdot x_i + \sum_i (bowl_{ir} + bat_{ir}) \cdot r_i - \left(\left(\sum_i bowl_{ix} - \sum_i bat_{ix} \right) \cdot x_i \right. \\ & \left. + \left(\sum_i bowl_{ir} - \sum_i bat_{ir} \right) \cdot r_i \right)^2 - Var((bowl_{ix} + bat_{ix})x_i) - Var((bowl_{ir} + bat_{ir})r_i) \end{aligned}$$

The first term calculates the performance index of chosen players from the auction pool. The second term calculates the performance index of retained players. The third term ensures that the team will have a balanced composition of batsmen and bowlers, and the variance term ensures an equitable distribution of good players in the team.

3.4 Constraints

1. **Team Size:**

$$18 \leq \sum_i x_i + \sum_i r_i \leq 25$$

2. **Budget Constraint:**

$$\sum_i b_i \cdot x_i + \sum_{k=1}^5 c_k \cdot z_k + \sum_{i \in U} r_i \cdot c \leq \text{Budget}$$

The first term is the cost of the players in the auction pool. The second term includes retention costs of capped players and the third term includes retention costs of uncapped players.

3. **The number of capped retained players and z_k relation:**

$$\sum_{i \in C} r_i = \sum_{k=1}^5 k \cdot z_k$$

4. **Only one retention count is 1:**

$$\sum_{k=1}^5 z_k \leq 1$$

5. **Overseas player limit:**

$$\sum_i y_{ix} \cdot x_i + \sum_i y_{ir} \cdot r_i \leq 8$$

6. **Maximum retained players:**

$$\sum_i r_i \leq 6$$

7. **Maximum capped and uncapped retained players:**

$$\sum_{i \in C} r_i \leq 5$$

$$\sum_{i \in U} r_i \leq 2$$

4 Result

The SCIP mixed integer non-linear programming solver was used to arrive at the optimal solution. To enable faster convergence, a limit of 5% was set on the duality gap.

1. We found the optimal team for RCB considering retained players.

Result:

Bought players: Sai Sudharsan, David Miller, David Warner, Devon Conway, Dinesh Karthik, Faf du Plessis, Karun Nair, Mandeep Singh, Tilak Varma, Quinton de Kock, Riyan Parag, Robin Uthappa, Shikhar Dhawan, Vijay Shankar, Wriddhiman Saha, Suresh Raina, Chris Lynn, Saurabh Tiwary, Heinrich Klaasen, Manoj Tiwary, Murali Vijay, Rajat Patidar

Retained players: Virat Kohli, AB de Villiers

2. We found the best possible team when starting from scratch (no retained players).

Result:

Bought players: Abhishek Sharma, Aiden Markram, Ajinkya Rahane, Ambati Rayudu, Sai Sudharsan, David Miller, David Warner, Dinesh Karthik, Faf du Plessis, Karun Nair, Tilak Varma, Quinton de Kock, Rahul Tripathi, Robin Uthappa, Shikhar Dhawan, Shreyas Iyer, Vijay Shankar, Wriddhiman Saha, Suresh Raina, Aaron Finch, Chris Lynn, Saurabh Tiwary, Heinrich Klaasen, Manoj Tiwary, Murali Vijay