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On Performance Measurement of Cricketers and Selecting an Optimum Balanced Team

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Abstract

A cricket squad that participates in a tournament generally comprises of fifteen players. A balanced squad contains players having different expertise like batting, bowling, wicket keeping, etc. Keeping in view the cricketing requirements, selecting an optimal squad is a difficult decision-making problem. In order to attain that, the study proposes a composite index to measure the performance of cricketers irrespective of their expertise. Then using a binary (0-1) integer programming method a balanced squad of 15 players is selected. To apply the tool to practice, optimum balanced squads are selected from amongst the Indian players who participated in the Indian Premier League (IPL), based on the proposed performance measure for different seasons. The team so selected is compared to the actual Indian team selected for the International Cricket Council (ICC) Twenty20 World Cups following the IPLs in the year 2009, 2010 and 2012. It is seen that the actual Indian team is not much variant to the optimal squad of ICC Twenty20 World Cup 2012 but things are different during the years 2009 and 2010. The optimization technique discussed in this study can be helpful for the balanced team selection of other team sports as well.

Keywords: Composite Index, Cricket, Integer Programming, Optimization, Performance Measurement, Sport

1. Introduction

The Twenty20 format of cricket is probably the most significant development of the game in the twenty first century. In 2003, faced with five straight years of falling attendances of spectators in the domestic cricket league, the English cricket authorities decided in favour of a shorter version of cricket (Saikia *et al.*, 2013). Stuart Robertson, the formerly marketing manager of the England and Wales Cricket board (ECB) proposed this twenty over-a-side cricket tournament. This new tournament is named as the Twenty20 cup. In the tournament, each side would bat for twenty overs and, in effect, the game had been transformed into one that could be finished in three hours—thus not requiring the day-long commitment by spectators to a limited over game (Gupta, 2009). After the success of Twenty20 cricket in England, it rapidly immersed in the most parts of the cricket-playing world.

Few years, after the introduction of Twenty20 format of cricket, in 2007, the International Cricket Council (ICC) organized the first Twenty20 World Cup in South Africa, which was clinched by India. The inaugural Twenty20 World Cup proved to be an incredible boost to this format of cricket in India (Gupta, 2009). Thereafter, Board of Control for Cricket in India (BCCI) set up a professional league for Twenty20 cricket called the Indian Premier League (IPL) in April, 2008. IPL attracted the world's top players and showcased the best of India's talent (Saikia and Bhattacharjee, 2011). Since a large number of Indian players participated in IPL, it provided the selectors with options for selecting a balanced national team from a host of players. In the years 2009 and 2010, the Twenty20 World Cups were held just following the IPL. Thus, the followers of this format of cricket believed that the experience of Indian players in the IPL would help them to perform well in the World Cup matches (Saikia *et al*., 2012). However, India performed poorly at the said Twenty20 World Cups.

Whether it is in casual conversation or public debate, the team selection strategies of many sports fall under scrutiny (Bretteny, 2010). Each cricket board appoints a committee of selectors generally comprising of veteran cricketers. The selectors use their experience and expertise to select the team based on recent performance of the available cricketers. The responsibility of the selectors is not only to choose the best players but a balanced team with in-form players from all the different expertise like specialist batsmen, spin bowlers, fast bowlers, all-rounders and wicket keepers.

This paper discusses an objective technique of selecting an optimal cricket team using binary (0-1) integer programming method. A pre-requisite of this objective technique is to develop a method to quantify the different abilities of the cricketers. Thus, first the performances of Indian cricketers are quantified based on their on-field performances in the different seasons of IPL. Then attempt is made to select an optimum cricket team from the available players. The optimum team is compared with the actual Indian team selected by the Indian cricket board for the corresponding Twenty20 World Cups. This shall enable the readers to understand how accurate the Indian selectors were in decision-making.

2. Review of Literature

Application of objective methods for optimum team selection in cricket is relatively new and the effect seems to be more noticeable after the introduction of various competitive leagues involving large budgets to buy the players (Ahmed *et al*., 2012). The authors who addressed the issue of team selection, on quantifying the performance of cricketers used different optimization tools for such selection. Kamble et al. (2011) presented a selection procedure using analytical hierarchical process to choose a subset of players from a universal set of cricketers comprising of batsmen, bowlers, all-rounders and wicket keepers. Two other works addressing the same issue are Lemmer (2011*a*) and Ahmed et al. (2012). While Lemmer (2011*a*) used integer programming to reach the solution, Ahmed et al. (2012) used evolutationary multi-objective optimization to choose the cricket team. Barr and Kantor (2004) used portfolio analysis to determine the set of batsmen who are supposed to be more suitable for a given one-day squad. Gerber and Sharp (2006) proposed an integer programming technique in order to select

a limited over squad of 15 players instead of a playing XI. The method included collecting the data from 32 prominent South African cricketers to select the ODI squad. Extending the same idea, Lourens (2009) selected an optimal Twenty20 South African cricket side based on performance statistics of a host of players who participated in the SA domestic Pro20 cricket tournament. Using an integer programming, Brettenny (2010) selected players for a fantasy league cricket team under certain pre-specified bugetary constraints, but with a progressive approach. This optimal team at each stage of the tournament, considered the performance of available cricketers upto the previous match. Though most authors used the binary integer programming tool for the purpose of the optimized team selection, yet they used different tools for measuring the performance of cricketers. Some authors used the traditional statistics like batting average, strike rate, etc. for quantifying performance of cricketers, while others tried to combine such traditional measures to a refined statistic to evaluate players' performance. Authors like Lourens (2009) and Brettenny (2010) combined/compared different refined measures forwarded by others in the process of optimal team selection.
However, optimal player selection for a cricket team can not be fair unless the best available performance measures are used (Lemmer, 2011*a*). Several performance measures have already been developed by different authors in this regard. Lemmer (2002) devised a measure known as combined bowling rate (CBR) to measure the performance of bowlers by combining the three traditional bowling statistics *viz.* bowling average, economy rate and bowling strike rate. Harmonic mean was used by Lemmer (2002) to combine the traditional bowling statistics. A comprehensive measure of batting performance (BP) to assess the performance of batsmen in limited over cricket was also developed by Lemmer (2004). The batting performance measure (BP) was a product of exponentially weighted batting average, standardized coefficient of consistency and standardized strike rate of the batsmen. Barr and Kantor (2004) proposed an alternative batting performance measure for comparing and selecting batsmen in limited over cricket. This measure is a weighted product of batting average and strike rate of the batsmen. Various indices are developed by Gerber and Sharp (2006) to measure the performance of batsmen, bowlers, all-rounders, wicket keepers, etc. A performance measure for wicket keepers is developed by Lemmer (2011*b*), combining the dismissal rate and a measure of batting performance. But all these performance measures are applicable to measure the performance of batsmen, bowlers or wicket keepers based on scorecard of a match. A match scorecard only provides the information of traditional performance statistics like batting average, strike rate, economy rate, etc. However, such statistics have severe limitations in assessing the true abilities of a players' performance (Lewis, 2005). Also, the different traditional performance statistics are in different units of measurement; therefore to assess a player's all-around performance, it is very difficult to combine them. All these shortcomings to measure the performances of the cricketers were well discussed by Lewis (2005).

An alternative measure of player performance is developed by Lewis (2005) that can be used to combine the batting and bowling ability of a player. However, that measure of Lewis (2005) is based on ball-by-ball information of matches. But, collecting ball-by-ball information from a match or a series of matches is a tedious job.

Therefore, it would be better if scorecard of the match can be utilized to quantify the on-field performance of the players. Thus, before selecting the optimum squad of Indian cricket team, an attempt has been made to develop a fair performance measure by combining the traditional performance statistics. This can be used to measure the performances of batsman, bowler, all-rounder and wicket keeper using scorecard of the matches. Then the optimum player selection of a cricket team is done using binary (0-1) integer programming model. This objective method of player selection helps to include players with varying skills like - opener, specialist batsman, all-rounder, spin bowler, fast bowler and wicket keeper.

3. Methodology

The methodology used for performing the task can be broadly classified into two sections. The first section introduces the performance measure that shall be used to quantify the feat of the cricketers in the matches of recent past (Subsection 3.1). The second section deals with the optimization model (Subsection 3.5).

3.1. Performance Measure

In cricket, different measures like batting average and strike rate that are mostly used to measure the performances of batsmen and bowling average, economy rate and bowling strike rate to measure the performance of bowlers. However, Lewis (2005) mentioned that the traditional measures of performances do not allow to combining the abilities of batting and bowling, as they are based on incompatible scales. Thus, the following performance measure is proposed to overcome the above-discussed limitation.
The performance measure of the i^{th} player is given by,

$$S_i = S_{i1} + S_{i2} + \delta_i \qquad \dots (1)$$

Where

$$\delta_i = \begin{cases} S_{i3}^{a_i} + S_{i4}^{1-a_i} - 1, & \text{if } i^{th} \text{ player is either a bowler or wicket keeper} \\ 0, & \text{if } i^{th} \text{ player is neither a bowler nor wicket keeeper} \end{cases}$$

where 'a_i' is an indicator variable with,

$$a_i = \begin{cases} 1, & \text{if } i^{th} \text{ player is a bowler} \\ 0, & \text{if } i^{th} \text{ player is a wicket keeper} \end{cases}$$

with, S_{i1} = Performance score for batting
S_{i2} = Performance score for fielding
S_{i3} = Performance score for bowling
S_{i4} = Performance score for wicket keeping

To measure the batting performance of a cricketer (S_{i1}), the factors considered are: batting average, strike rate of the batsman and average percentage contribution to the team total (*cf.* Saikia et al., 2012). The values of these factors for each player are normalized and then weights of these factors are calculated based on their relative importance. All the normalized scores for the considered factors are multiplied by their corresponding weights and then added together to get S_{i1}. The details of the normalization and weighting technique are explained in subsections 3.2 and 3.3.

The factors considered to quantify the fielding performance of a cricketer (S_{i2}) are: number of catches taken by the player as a fielder and number run out caused by the player in a match or series of matches. Except these two factors, the other fielding information of a player is not available in scorecard of a match and hence they cannot be included. Thus, only these two factors are considered for fielding performance of a cricketer. The values of these two factors for each player are normalized and then weights are calculated based on their relative importance. All the normalized scores for these two factors are multiplied by their corresponding weights and then added together to get S_{i2} (*cf.* subsection 3.2 and 3.3 respectively).

Similarly, while computing the performance score of bowler (S_{i3}) the factors considered are: bowling average, economy rate and strike rate of the bowler. The values of these factors for each player are normalized and then weights of these factors are calculated based on their relative importance (*cf.* subsections 3.2 and 3.3). As mentioned earlier, all the normalized scores for the considered factors are multiplied by their corresponding weights and then added together to get S_{i3}.

In the same way, to measure the performance of a wicket keeper (S_{i4}) the different factors considered are: number of catches taken per match, number of stumping per match and number of bye runs conceded per match. Here the phrase 'per match' means the number of matches when the player kept the wickets for his team. This is because some of the teams have more than one player in their playing eleven who are capable of wicket keeping. Similarly, the values of these factors for each player are normalized and then weights are calculated. Thereafter, the normalized scores of the factors are multiplied by their corresponding weights (*cf.* subsections 3.2 and 3.3) and then added together to get S_{i4}.

3.2. Normalization

The developed performance measure is a linear combination of traditional performance statistics under the abilities of batting, fielding, bowling and wicket keeping. To overcome the limitation that different measures have different units of measurement normalization is essential. Normalization aids to eliminate the unit of measurement and variability effect of all the traditional performance measures. Based on normalization, the traditional performance measures under the abilities of batting, bowling and wicket keeping come within a similar range from 0 to 1. Since normalization makes the measures unit free, so they can be combined through addition. Out of the different factors considered for performance measurement, some are having positive dimension like batting average, batting strike rate, number of stumping, etc. as they are directly related to the ability of a player. While some of the factors like economy rate, number of bye runs conceded, etc. have reverse dimension as they are inversely related to the ability of a player. Therefore, proper care shall be taken in the formula while normalizing such variables.

Let X_{ijk} be the value of the j^{th} factor (*i.e.* batting average, strike rate, etc.) for the i^{th} player in the k^{th} ability (*i.e.* batting, fielding, bowling and wicket keeping). Now, if the factor is positively associated with the ability of a player then it is normalized as

$$Y_{ijk} = \frac{X_{ijk} - \min(X_{ijk})}{\max(X_{ijk}) - \min(X_{ijk})} \qquad \dots (2)$$

and if the factor inversely allied with the ability of a player then it is normalized as

$$Y_{ijk} = \frac{\max(X_{ijk}) - X_{ijk}}{\max(X_{ijk}) - \min(X_{ijk})} \qquad \dots (3)$$

3.3. Determination of Weights

While simple averages provide an equal importance to all the variables, a composite measure is weighted and the relative importance of the variables can be considered. Iyenger and Sudarshan (1982) assumed that the weights vary inversely proportional to the variation in the respective variables. This method is applied to determine the weights of the different factors.

Let Y_{ijk} be the normalized value of the i^{th} player for the j^{th} factor of the k^{th} ability. Now if w_{jk} represents the weight of the j^{th} factor under the k^{th} ability, then it is calculated as

$$w_{jk} = \frac{C_k}{\sqrt{\underset{i}{Var}(Y_{ijk})}}, \qquad j = 1, 2, 3 \text{ and } k = 1, 3, 4 \qquad \dots (4)$$

where $\sum_{j=1}^{3} w_{jk} = 1$ for $k = 1, 3, 4$

C_k is a normalizing constant that follows $$C_k = \left[\sum_{j=1}^{3} \frac{1}{\sqrt{\underset{i}{Var}(Y_{ijk})}}\right]^{-1}$$

Since only two factors are considered under fielding ability *viz.* number of catches taken and run outs; therefore, if w_{jk} represent the weight of the j^{th} factor under the fielding ability ($k = 2$) then it is calculated as

$$w_{jk} = \frac{C_k}{\sqrt{\underset{i}{Var}(Y_{ijk})}}, \qquad j = 1, 2 \text{ and } k = 2 \qquad \text{where } \sum_{j=1}^{2} w_{jk} = 1 \text{ for } k = 2 \qquad \dots (5)$$

C_k is a normalizing constant that follows $$C_k = \left[\sum_{j=1}^{2} \frac{1}{\sqrt{\underset{i}{Var}(Y_{ijk})}}\right]^{-1}$$

The weights as discussed in Iyenger and Sudarshan (1982) act as variance stabilizer to the normalized variables and restrict the dominance of any of the variables in the composite index.

3.4. Computation of Performance Score

The normalized factors after multiplied by the corresponding weights are combined in a linear approach to get the composite index. This index is the performance measure of each cricketer (*i.e.* S_i). The performance score of S_{i1}, S_{i2}, S_{i3} and S_{i4} for batting, fielding, bowling and wicket keeping are computed as follows.

The performance scores for batting (k = 1), fielding (k = 2), bowling (k = 3) and wicket keeping (k = 4) of the i^{th} player is calculated by

$$S_{ik} = \sum_{j=1}^{n_k} w_{jk} Y_{ijk} \; ; \qquad \ldots (6)$$

Where n_k = 4 for k = 1, 3 and 4 and n_2 = 2.

On obtaining the values S_{ik} (for k = 1, 2, 3 and 4) the performance measure S_i of the i^{th} player is computed using equation (1). The performance measures of all the players are computed and then converted into corresponding performance index (P_i). The performance index of the i^{th} player is denoted by P_i and is given by,

$$P_i = \frac{S_i}{\max_i (S_i)} \qquad \ldots (7)$$

The performance index for each player is a number lying between zero and one (*i.e.* $0 < P_i \leq 1$). The higher value of the performance index better is the performance of a player.

3.5. The Optimization Model

The optimization technique used for team selection for the ICC Twenty20 World Cups after the corresponding seasons of IPL is a binary (0-1) integer-programming model. The solution to the problem is attained using the Solver add-in available in Microsoft Excel. The theory and procedure for solving integer programming is discussed in details by Ragsdale (2007).

Any given country featuring in the ICC Twenty20 World Cup has to select a team of 15 players. Thus, once the values of performance score (P_i) for the entire set of available Indian players is calculated, the next step is to select that combination of 15 players which maximizes the total performance score. The most common combination of players as per their expertise that the selectors of BCCI followed for the three Twenty20 World Cups comprises of two openers, one wicket keeper, at least three specialist batsmen, at least two all-rounders, at least three fast bowlers and at least two spinners. This combination is used while defining the constraints in the optimization model.

For the programming model, a set of binary variables are defined that shall be helpful in equating the objective function and the constraints.

θ_i = 1 (0), if the i^{th} player is selected in the optimum team (Otherwise)
b_i = 1 (0), if the i^{th} player is an opening batsman (Otherwise)
c_i = 1 (0), if the i^{th} player is a specialist batsman but not an opener (Otherwise)
d_i = 1 (0), if the i^{th} player is a spinner (Otherwise)
e_i = 1 (0), if the i^{th} player is a fast bowler (Otherwise)
f_i = 1 (0), if the i^{th} player is an all-rounder (Otherwise)
g_i = 1 (0), if the i^{th} player is a wicket keeper (Otherwise)

Let k be the total number of potential players who are considered for selection, then the function that is to be maximized is given by,

$$Z = \sum_{i=1}^{k} \theta_i P_i \qquad \ldots (8)$$

For the current problem, the following constraints are used.

$\sum_{i=1}^{k} \theta_i = 15$ # to ensure that exactly 15 players are selected

$\sum_{i=1}^{k} \theta_i b_i = 2$ # to ensure that exactly two openers are selected

$\sum_{i=1}^{k} \theta_i c_i \geq 3$ # to ensure that at least 3 middle order batsmen are selected

$\sum_{i=1}^{k} \theta_i d_i \geq 2$ # to ensure that at least 2 spin bowlers are selected

$\sum_{i=1}^{k} \theta_i e_i \geq 3$ # to ensure that at least 3 fast bowlers are selected

$\sum_{i=1}^{k} \theta_i f_i \geq 2$ # to ensure that at least 2 all-rounders are selected

$\sum_{i=1}^{k} \theta_i g_i = 1$ # to ensure that exactly 1 wicket keeper is selected

3.6. Data Consideration

The data related to the performance of the Indian players in IPL 2009, 2010 and 2012 are considered as the basis of selection of the players for the optimum team of the corresponding years. In these years, IPL was just held before the 2009, 2010 and 2012 ICC Twenty20 World Cups. No Twenty20 World Cup was scheduled by ICC in the year 2011. The followers of this format of cricket believed that the experience of Indian players in the IPLs would help them to perform better in the World Cups. However, the Indian team's debacle performance in the said Twenty20 World Cups raises a crucial question, "Whether the team selection in the ICC Twenty20 World Cup was appropriate?" The information of on-field performance of the cricketers is collected from the website *www.espncricinfo.com*. To measure the performance of players it is necessary that players' statistics for large number of games should be considered. The expectations regarding level of performance cannot be gauged fairly from only one match and therefore individual performances across a series of matches are required to provide a suitable frame of reference (Bracewell and Ruggiero, 2009). Thus, some selection criterion needs to be set up while considering the players for performance measurement. Only Indian players are selected based on the following criteria from the 2009, 2010 and 2012 seasons of IPL.

For batsmen:
a) Played at least five innings
b) Faced at least 60 balls
c) Batting average greater than or equal to 10

For bowlers:
a) Played at least five matches
b) Delivered at least 60 balls
c) Dismissed at least 3 batsmen

For wicket keepers:
a) Played at least five matches as wicket keeper
b) Dismissed at least 3 batsmen and
c) Satisfied all three conditions for batsmen selection

For all-rounders: the conditions laid down for both the batsmen and bowlers should be satisfied.

There are 47, 51 and 58 Indian players from IPL 2009, 2010 and 2012 respectively who satisfied the above-mentioned criteria. In Table 1, the expertise wise breakups of the players are provided.

Table 1. Break-up of the training sample from various IPL seasons

	2009	2010	2012
Opening Batsman	4	7	7
Middle-order Batsman	8	13	16
Wicket Keeper	4	4	7
Spin Bowler	9	9	9
Fast Bowler	16	13	14
All-rounder	6	5	5
Total	47	51	58

4. Results and Discussions

The weights of the different factors for 2009, 2010 and 2012 seasons of IPL are calculated based on the equations (4) and (5) and are given in Table 2. The corresponding IPL performance scores of players are calculated using equation (7).

Table 2. Weights of the factors in different abilities

	Factors	**IPL (2009) Weights**	**IPL (2010) Weights**	**IPL (2012) Weights**
Batting	Batting average	0.332	0.317	0.306
	Strike rate	0.346	0.357	0.371
	Average percentage of contribution to the team total	0.322	0.326	0.323
Fielding	Catch	0.566	0.433	0.418
	Run out	0.434	0.567	0.582
Bowling	Bowling average	0.353	0.305	0.315
	Economy rate	0.342	0.343	0.398
	Bowling strike rate	0.304	0.352	0.287
Wicket Keeping	Catches taken per match	0.343	0.317	0.291
	Run outs per match	0.325	0.337	0.347
	Bye runs conceded	0.332	0.346	0.362

Microsoft Excel add-in 'Solver' is used by maximizing the objective function *Z* subject to the given cricketing requirements (*i.e.* constraints). The result of the optimization model is given in Table 3 and Table 4.

Table 3. Performance score (Value of Z) of the entire team for the different years

Year	Performance score (Value of Z)		Difference
	Optimum Team	Actual Team	
2009	12.945	9.571	3.374
2010	11.995	8.119	3.876
2012	8.654	7.032	1.622

Table 3 provides an indication that the actual teams selected by BCCI were lesser in strength compared to the optimum teams in all the three cases. But less difference between the Performance Score (Z) for the team selected for the 2012 World Cup with that of the optimum team can be noted. This indicates that team selection was better in 2012 compared to the other years.

Table 4. Optimal Squad and Actual Indian Team for ICC Twenty20 World Cups

Twenty20 World Cup 2009		Twenty20 World Cup 2010		Twenty20 World Cup 2012	
Actual Squad	**Optimum Squad**	**Actual Squad**	**Optimum Squad**	**Actual Squad**	**Optimum Squad**
V Sehwag	V Sehwag$^{@}$	M Vijay	M Vijay$^{@}$	MS Dhoni	MS Dhoni^{w}
G Gambhir	G Gambhir$^{@}$	S Raina	S Raina*	V Sehwag	V Sehwag$^{@}$
S Raina	S Raina*	Y Singh	Y Singh*	G Gambhir	G Gambhir$^{@}$
R Sharma	R Sharma*	H Singh	H Singh$^{\$}$	S Raina	S Raina^{+}
H Singh	H Singh$^{\$}$	Z Khan	Z Khan$^{\#}$	R Sharma	R Sharma^{+}
RP Singh	RP Singh$^{\#}$	KD Kartik	KD Kartik ^{w}	V Kohli	AT Rayudu^{+}
P Ojha	P Ojha$^{\$}$	Y Pathan	AB Dinda$^{\#}$	M Tiwari	Mandeep Singh^{+}
Y Singh	V Kohli^{+}	RA Jadeja	S Tiwary^{+}	I Pathan	I Pathan*
Y Pathan	A Mishra$^{\$}$	G Gambhir	S Badrinath$^{@}$	Y Singh	RA Jadeja*
I Shamra	A Nehra$^{\#}$	P Kumar	V Kohli^{+}	Z Khan	Z Khan$^{\#}$
P Kumar	NV Ojha^{+}	A Nehra	SB Jakati$^{\#}$	L Balaji	L Balaji$^{\#}$
MS Dhoni	KD Karthik^{w}	MS Dhoni	AT Rayudu^{+}	AB Dinda	UT Yadav$^{\#}$
RA Jadeja	P Chawla$^{\$}$	P Chawla	R Ashwin$^{\$}$	R Ashwin	R Ashwin$^{\$}$
Z Khan	TL Suman^{+}	R Sharma	SK Trivedi$^{\#}$	H Singh	H Singh$^{\$}$
I Pathan	M Patel$^{\#}$	R Vinay Kumar	P Ojha$^{\$}$	P Chawla	P Chawla$^{\$}$

Note: 'w'= wicket keeper, '@'= opener, '+'= batsman, '*'= all-rounder, '#'= fast bowler and '$'= spin bowler

Table 4 provides the list of selected players for the optimum teams along with the actual teams of the said seasons. The actual teams have 7, 6 and 11 players in common with the corresponding optimum teams. However, all-rounder Y Singh is not considered for selection in the optimum squad for non-participation in IPL 2012, as he was suffering from cancer. Considering Y Singh's services to Indian cricket and his recovery from cancer the selectors decided to reward him a place in the Indian team. This is definitely an appreciable gesture from the selectors. But an objective model, like the one discussed in the paper can never incorporate such subjective decisions.

Further, MS Dhoni is not selected as a wicket-keeper in 2009 and 2010 seasons of Twenty20 World Cups based on the optimization method. However, the Indian selectors were not ready to take such decision to eliminate Dhoni from optimal squad, who clinched the inaugural Twenty20 World Cup title in 2007 for India. Selection of the captain is a vital decision for a team. Also the leadership qualities are difficult to quantify. As MS Dhoni shall claim his position in the squad being the captain, so the last constraint (*i.e.* exactly one wicket-keeper) that was used for optimization shall be removed. In the optimal selection of 2009 ICC Twenty20 World Cup, KD Karthik is selected as wicket-keeper. But MS Dhoni's selection as a captain in the squad would restrict the inclusion of KD Karthik in the team, in spite of his objective selection.

The players common to both the actual squad and the optimum squad in 2009 are V Sehwag, G Gambhir, S Raina, R Sharma, H Singh, RP Singh and P Ojha and in 2010 are M Vijay, S Raina, Y Singh, H Singh, KD Kartik and Z Khan. So, the Indian squads of BCCI in both these seasons of ICC Twenty20 World Cups are far from optimal.

In 2012 ICC Twenty20 World Cup, the difference between the teams seems to be amongst the specialist batsmen. AT Rayudu and Mandeep Singh are included in the optimum team instead of V Kohli and M Tiwari. However, considering the form of V Kohli in the international circuit at that time, it seems a good decision to include him. Thus, overall it may be concluded that the selectors of BCCI give a very balanced team to MS Dhoni in 2012 compared to the previous two years *i.e.* 2009 and 2010.

5. Conclusion and Future Scope of the Study

Selecting the optimal squad keeping in view the cricketing requirements, from available players having different abilities is a difficult task. Along with subjectivity, many other factors are involved in the selection of a cricket team (Lemmer, 2011*a*). For example- inclusion of a player in the optimal squad of a team depends on the strength of the opponent, pitch condition, format of the game, experience of the players, etc. Also sometimes selectors may want to give another chance to an experienced player who is out form (Lemmer, 2011*a*). The difficulty of such subjective state of affairs can be traded by using objective method like the one, applied in this paper. However, the selection of the players in the optimal squad is subject to the set of given constraints and the tool used for quantifying their performance. If the constraints or the performance measurement tools are changed then players in the optimal squad may also get altered.

The optimization technique discussed in this paper helps to decide the optimal squad of a given team objectively, for any given tournament based on the previous performances of the players. Another area of interest may be to decide an optimum XI from a given squad of players given the strength of the opposition and the pitch conditions. In the previous studies with similar objective like Gerber and Sharp (2006), Lourens (2009), Brettenny (2010), Kamble et al. (2011), etc. the optimum teams were found to have few players different from the actual team as in case of this study. However, the current work selects optimum teams for the same cricket board for three consegutive seasons and extends it to a longitudinal study. The outcome reflects that, with the passage of time the Indian selectors are giving more importance to the performance of players in IPL while selecting the national squad. However, this claim needs to be verified for the subsequent years. Finally, it may be concluded in support of avowal given by Lemmer (2011*a*) that to select an optimal squad before the any given tournament, close co-operation between the selectors and the cricket statisticians are needed.

This procedure of optimum team selection can be extended to several other team sports like football, baseball, etc. Ahmed et al (2012) mentioned that in American Football, each team has 11 players on the field and a National Football League (NFL) team has a limit of 53 players on their roster. Now, if we can classify the players by their expertise *viz.* offense, defense, kicker, etc. then based on the previous record of on-field performance, an optimum football team can be selected using the proposed binary optimization method. The appropriate constraints can be defined on the basis of ability of a player to play well in different positions in American football. Same procedure can be applied in optimum baseball team selection also, as the game has some similarity to that of cricket.

6. References

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