Determining the Winner of a Tied Limited-Overs Cricket Match Using Batting and Bowling Indices

Rohit Chakravorty
Mathematics BSc, University of Leicester

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Abstract: This paper outlines an alternative method of determining the winner of a tied One-Day International cricket match to the boundary count rule invoked during the 2019 World Cup between England and New Zealand. This is done by quantifying the performance of the teams using Batting and Bowling Indices and comparing their expected values to those achieved in the match. This contrast is reflected in a different figure known as a Performance Index. Combining the Performance Indices for the two disciplines gives the Team Performance Index, by which a winner can be decided.

1. Introduction

1.1 Cricket Basics

Cricket is the second most popular sport in the world after football, with an estimated 2.5 billion fans worldwide [1].

The sport itself is played between two teams of 11 players who take it in turns to bat and bowl, with the objective of scoring more *runs* than the other side. A *batsman* on the batting team aims to score as many runs as possible until they lose their *wicket* to the fielding team. Runs are scored by striking the ball into or over a boundary rope placed at the edge of the field (known as a *boundary,* yielding four or six runs respectively), or by running between two sets of *stumps* located at either side of the *pitch* (yielding one run each time the batsman reaches the opposing set of stumps). The aim of the bowling and fielding team is to minimise the number of runs scored by the batting team and to dismiss each batsman (get them *'out'*), known as *taking wickets.* Balls are bowled overarm in sets of six known as *overs*. Wickets can be taken in a variety of ways, the most prevalent being: a *fielder* catching a ball that has been hit up into the air (getting '*caught'),* a *bowler* hitting the stumps that the batsman is protecting (getting *'bowled'*), and a fielder hitting the stumps before the batsmen are able to complete the run (getting *'run out'*). Extra runs are awarded mainly for *wides* (bowling a ball that is out of reach of the batsman) and *no balls* (a bowler overstepping the white line at the end of their run up). [2]

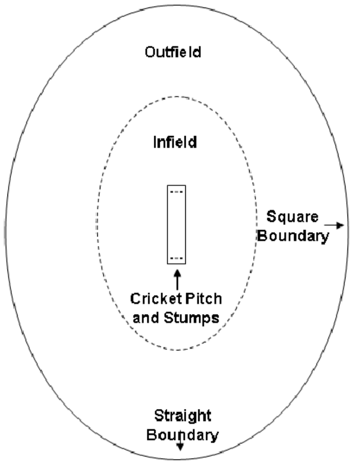

Figure 1: A standard cricket field [3]

Cricket exists in various forms, with one-day cricket introduced in the 1960s as an alternative to more traditional structures which can take up to five days to end. The established type of one-day cricket is played over 50 overs and is called a One-Day International (ODI). Each set of 50 overs is known as an *innings.* ODIs are the preferred format for the Cricket World Cup, which occurs every four years.

ODIs and other forms of one-day cricket end in a tie when the scores are level, and are very rare, with only 40 ODIs ending in a tie in its 50-year history. However, since 1999, ties have occurred more frequently than before with 24 ties. In addition, there has been at least one tied match in every World Cup tournament in this time period, except for the 2015 World Cup. [4]

1.2 Tiebreakers

When a result is required, such as in the knockout stage of a tournament, tiebreaker methods are used.

The first method used was the Bowl-Out (also known as a bowl-off). This is where five bowlers from each side deliver one or two balls each at an exposed set of stumps [5]. If there are the same number of wickets from each side after five bowlers the process is repeated, and the result is decided by 'sudden death' (the winner is the first side to take the lead). This procedure was first used in 1991 in a domestic tournament but was never required on an international stage.

The Super Over (also known as the one-over eliminator) was introduced into ODI cricket at the 2011 Cricket World Cup knockout stage as a replacement for the Bowl-Out [6]. Here both teams would play a single additional over of six balls, with the side with the higher score being declared the winner. Should the Super Over also result in a tie, the boundary count back rule would be applied: the winner would be decided by the number of boundaries scored in the match.

This method remained unused until the 2019 Men's Cricket World Cup Final between England and New Zealand. Here, scores were level after the Super Over following a tied match, leading to England being declared the winner on the boundary count back rule (scoring 26 boundaries compared to New Zealand's 17). Following the match, the rule garnered criticism for not being an comprehensive way of deciding which team played better.

2. Aim of Research

This paper seeks to provide an alternative to the boundary count rule by creating a metric that is more representative of the overall performance of each team. Such a statistic does not exist in cricket currently. This metric is then used to decide the winner when the tiebreaking method used has ended in a tie. To achieve this, expressions are derived by which the performances of the teams can be quantified. These expressions are then applied to the real-life example of the 2019 World Cup Final to see whether England winning the match was the correct result.

3. Methodology

Quantifying the batting and bowling performance simply by the number of runs scored and the number of wickets taken does not fully encompass how well each player has played. Therefore, equations for Batting and Bowling Indices outlined by Croucher (2000) [7] are used for analysis.

3.1 Batting Index

Two key batting statistics are:

- $Batting\ Average = \frac{Number\ of\ Runs\ Scored}{Number\ of\ Times\ Dismissed}$, i.e. the average runs scored in each innings by a single batsman

- $Batting\ Strike\ Rate\ (S/R) = \frac{Number\ of\ Runs\ Scored}{Number\ of\ Balls\ Faced} \times 100$, i.e. the number of runs that would be scored by a batsman in 100 balls

Both the batting average and strike rate are necessary for evaluating how well each batsman has played. This is because a batsman that can average 60 runs but has a strike rate of 10 is not particularly useful as they would take up too many balls to reach that score. Moreover, a batsman with a strike rate of 150 but an average of 10 could score runs quickly but the number of runs scored would be insignificant. Thus, an ideal batsman would be one that could score a great deal of runs at a respectable pace.

The question then becomes how the batting average and strike rate can be combined to produce a valuable result, known as the *Batting Index*. One could take the sum of both, however, as discussed by Kumar (2014) [8], two batsmen could have the same Batting Index but be wildly different in terms of their impact on the innings.

Hence, the *Batting Index* for an individual batsman is defined as:

$$\boldsymbol{Batting\ Index = Batting\ Average \times Batting\ Strike\ Rate} \quad (1)$$

A batsman cannot be dismissed more than once in a limited-overs game, so the Batting Index for a single match can be defined as:

$$\boldsymbol{Match\ Batting\ Index = Number\ of\ Runs\ Scored \times Batting\ Strike\ Rate} \quad (2)$$

It is possible for a batsman to be run out without facing a ball, hence in these situations it would not be feasible to evaluate the Match Batting Index as calculating the Batting Strike Rate would require dividing by zero.

Another important remark to make from this is that the **higher** the batting index, the better the **batsman** has performed.

3.2 Bowling Index

Following a similar process, the *Bowling Index* for an individual bowler can be expressed as:

$$\boldsymbol{Bowling\ Index = Bowling\ Average\ \times Bowling\ Strike\ Rate} \quad (3)$$

Where:

- $Bowling\ Average = \frac{Runs\ Conceded}{Wickets\ Taken}$, i.e. the runs conceded per wicket taken by each bowler
- $Bowling\ Strike\ Rate\ (S/R) = \frac{Number\ of\ Balls\ Bowled}{Wickets\ Taken}$, i.e. the number of balls bowled by a bowler to take one wicket

For a single limited-overs cricket match, the *Match Bowling Index* for each bowler is equal to their Bowling Index for that game.

It is possible that a bowler may not take a wicket in the match, thus one should note that it is not possible to calculate the Bowling Index in these cases as it would require dividing by zero. Therefore, the main use of the Match Bowling index is in indicating the wicket taking ability of the various bowlers.

The *economy rate* (average runs conceded by the bowler each over) is not considered for the Bowling Index as this would be reflected in the run scoring capability of the opposing batting team.

A key observation to make from (3) is that the **lower** the bowling index, the better the **bowler** has performed.

3.3 Performance Index

For batsmen, this is defined as:

$$\boldsymbol{Batting\ Performance\ Index = \frac{Match\ Batting\ Index}{Expected\ Batting\ Index}} \quad (4)$$

Where:

- The Match Batting Index is calculated using (2)
- The *Expected Batting Index* is calculated by putting career figures for the batting average and strike rate into (1)

This is changed slightly for bowlers:

$$\boldsymbol{Bowling\ Performance\ Index = \frac{Expected\ Bowling\ Index}{Match\ Bowling\ Index}} \quad (5)$$

Where:

- The Match Bowling Index is calculated using (3) with individual match statistics for the player.
- The *Expected Bowling Index* is calculated by putting career figures for the bowling average and strike rate into (3)

3.4 Team Performance Index

This is the statistic that will be used to compare the overall performance of each team, with batting and bowling holding equal weight.

Firstly, the mean performance index for each speciality is taken, and is done for each team. This is accomplished by using the formula:

$$\boldsymbol{Mean\ Performance\ Index\ (MPI) = \frac{\sum_{i=1}^{n} Performance\ Index\ for\ player\ i}{n}} \quad (6)$$

Where n is the number of players used for analysis in each facet of cricket.

These two means can then be combined to give a *Team Performance Index.*

To derive an expression for the Team Performance Index, the definition for a combined mean [9] is required, which can be stated as:

$$x_c = \frac{m \cdot x_a + n \cdot x_b}{m + n}$$

Where:

- x_c is the combined mean
- x_a is the mean of the first set
- m is the number of items in the first set
- x_b is the mean of the second set
- n is the number of items in the second set

Applying this to cricket, by letting batsmen and bowlers be treated as different sets, the combined mean expression leads to the following equation:

$$\boldsymbol{Team\ Performance\ Index\ (TPI)} = \frac{\boldsymbol{n_{bat,t} \cdot MPI_{bat,t} + n_{bowl,t} \cdot MPI_{bowl,t}}}{\boldsymbol{n_{bat,t} + n_{bowl,t}}} \quad (7)$$

Where:

- $MPI_{bat,t}$ is the *Mean Batting Performance Index* for team t
- $n_{bat,t}$ is the number of batsmen used for analysis from team t
- $MPI_{bowl,t}$ is the *Mean Bowling Performance Index* for team t
- $n_{bowl,t}$ is the number of bowlers used for analysis from team t

The Team Performance Index gives an indication of how well a side has performed in the match compared to their expected performance. Comparing this metric between the two teams in the match shows which side gave an overall better performance in each match. From this, the worthy winner for a tied limited-overs cricket game can be chosen, providing a more rigorous alternative to the boundary count rule used previously.

4. Applying method to the 2019 Cricket World Cup Final

These equations are then applied to the 2019 Cricket World Cup Final between England and New Zealand which took place on 14th July 2019 at Lord's Cricket Ground in England. The results from these calculations can then be used to determine who the worthy winner should have been.

4.1 Match Batting Index

Using batting figures from the full scorecard provided by ESPN Cricinfo [10], the Match Batting Index for each Batsman in their respective teams is presented below. Any batsmen that did not face a single ball are excluded from analysis.

Table 1: Match batting records for New Zealand

Player	Match runs	Match S/R	Match Batting Index
M Guptill	19	105.55	2005.45
H Nicholls	55	71.42	3928.1
K Williamson	30	56.6	1698
R Taylor	15	48.38	725.7
T Latham	47	83.92	3944.24
J Neesham	19	76	1444
C de Grandhomme	16	57.14	914.24
M Santner	5	55.55	277.75
M Henry	4	200	800
T Boult	1	50	50

Table 2: Match batting records for England

Player	Match runs	Match S/R	Match Batting Index
J Roy	17	85	1445
J Bairstow	36	65.45	2356.2
J Root	7	23.33	163.31
E Morgan	9	40.9	368.1
B Stokes	84	85.71	7199.64
J Buttler	59	98.33	5801.47
C Woakes	2	50	100
L Plunkett	10	100	1000
J Archer	0	0	0

4.2 Match Bowling Index

The bowling figures from the same scorecard [10] are used to find the Match Bowling Index for each bowler and are grouped by each side. All bowlers that failed to take a wicket are excluded from calculations.

Note that values for the Bowling Average and Bowling Strike Rate for the match cannot be directly taken from the scorecard. Therefore, these are calculated using the relevant formulae above, and using the fact that one over is equivalent to six balls bowled.

These results are shown in the tables below:

Table 3: Match bowling records for New Zealand

Player	Wickets Taken	Runs Conceded	Balls Bowled	Match Bowling Average	Match Bowling S/R	Match Bowling Index
M Henry	1	40	60	40	60	2400
C de Grandhomme	1	25	60	25	60	1500
L Ferguson	3	50	60	16.67	20	333.33
J Neesham	3	43	42	14.33	14	200.67

Table 4: Match bowling records for England

Player	Wickets Taken	Runs Conceded	Balls Bowled	Match Bowling Average	Match Bowl S/R	Match Bowling Index
C Woakes	3	37	54	12.33	18	222
J Archer	1	42	60	42	60	2520
L Plunkett	3	42	60	14	20	280
M Wood	1	49	60	49	60	2940

4.3 Expected Batting/Bowling Indices

When calculating the Expected Batting/Bowling Indices for the respective teams, the question occurs as whether to use figures from every game in a player's career, or just those that were played in the country that the current match is taking place in. This is the same as testing whether the country that the match was played in has a statistically significant effect on the player's performance. Tournament specific data is **not** considered as the timeframe between each World Cup, as well as the difficulty of making it to a World Cup squad, means very few games are played in this dataset and can lead to inaccuracies during analysis. This statement also holds for other cricket tournaments outside of the World Cup.

To compare the two datasets, the searchable cricket database from ESPN Cricinfo [11] is used to find player statistics, both for their whole ODI career, and for those ODI matches which were played in England. Both datasets are filtered for matches played up until but not including 14th July 2019.

Next, as the comparison is done for the same group of players, the two-tailed paired sample t-test is applied. The two-tailed test is preferred to the one-tailed test as the difference can be either positive or negative. The test will show whether the difference between the two population means for the respective indices are statistically significant by testing the following hypotheses:

$$H_0: The\ difference\ between\ the\ means\ is\ due\ to\ chance$$

$$H_1: The\ difference\ between\ the\ means\ is\ statiscally\ significant$$

Firstly, looking at the batting statistics for each team using these conditions:

Table 5: Career and England-specific batting records for England

Player	***Career ODI average***	***Career ODI S/R***	***Career Batting Index***	***ODI average in England***	***ODI S/R in England***	***Batting Index in England***
J Roy	43.12	107.54	4637.12	48	110.98	5327.04
J Bairstow	47.88	104.86	5020.70	59.09	106.96	6320.27
J Root	51.76	87.66	4537.28	50.98	91.23	4650.91
E Morgan	39.88	91.38	3644.23	44.6	97.57	4351.62
B Stokes	39.36	94.23	3708.89	47.42	93.99	4457.01
J Buttler	40.68	120.24	4891.36	47.34	122.38	5793.47
C Woakes	25.19	90.24	2273.15	26.11	88.01	2297.94
L Plunkett	21.2	102.74	2178.09	19.73	139.62	2754.70
J Archer	4.33	61.9	268.03	4.33	61.9	268.03

Using the data in *Table 5* and running the paired sample t-test with $\alpha = 0.05$, the p-value obtained is 0.0049. Therefore, as $P(T \leq t) < \alpha$, the null hypothesis (H_0) can be rejected, and there is a statistical difference between England batting in their home country versus their mean career Batting Index (i.e. the alternative hypothesis H_1 is accepted). In this case, the mean Batting Index for England playing at home is 4024.55 which is higher than their career mean of 3462.10.

Table 6: Career and England-specific batting records for New Zealand

Player	***Career ODI average***	***Career ODI S/R***	***Career Batting Index***	***ODI average in England***	***ODI S/R in England***	***Batting Index in England***
M Guptill	42.35	87.3	3697.16	40.95	93.81	3841.52
H Nicholls	33.28	83.07	2764.57	12	50	600
K Williamson	48.04	82	3939.28	71.73	86.98	6239.08
R Taylor	48.05	83.11	3993.44	44.72	80.6	3604.43
T Latham	32.08	82.33	2641.15	15.42	67.5	1040.85
J Neesham	31.48	99.43	3130.06	28.88	82.01	2368.45
C de Grandhomme	28.04	109.78	3078.23	24.85	108.07	2685.54
M Santner	27.06	88.24	2387.77	21	94.97	1994.37
M Henry	15.92	99.04	1576.72	5.2	74.28	386.23
T Boult	9.56	73.91	706.58	4.5	47.36	213.12

Using *Table 6* and running the same test for the New Zealand batting line-up gives a two-tail p-value of 0.22. Here, $P(T \leq t) > \alpha = 0.05$, so the null hypothesis is accepted and so it can be concluded that there is no statistical difference between the two means.

After this, the dataset is sorted to find the bowling statistics for each team:

Table 7: Career and England-specific bowling records for England

Player	***Career ODI average***	***Career ODI S/R***	***Career Bowling Index***	***ODI average in England***	***ODI S/R in England***	***Bowling Index in England***
C Woakes	30.86	32.9	1015.29	32.31	34.7	1121.16
J Archer	23.95	30.7	735.27	23.19	29.9	693.38
L Plunkett	30.06	30.8	925.85	29.77	30.8	916.92
M Wood	38.93	42	1635.10	36.62	40.6	1486.77

With the figures in *Table 7*, the paired sample t-test for the bowling statistics produces a two-tailed p value of 0.69. Hence there is no statistical difference between the two mean Bowling Indices for the England team.

Table 8: Career and England-specific bowling records for New Zealand

Player	***Career ODI average***	***Career ODI S/R***	***Career Bowling Index***	***ODI average in England***	***ODI S/R in England***	***Bowling Index in England***
M Henry	26.34	29	763.86	33.5	35.1	1175.85
C de Grandhomme	44.39	53.7	2383.74	37.4	49.2	1840.08
L Ferguson	26.07	28.7	748.21	19.94	24.5	488.53
J Neesham	31.62	30.8	973.90	24.66	27.2	670.75

Now, running the test again with the data in *Table 8*, the p-value produced is 0.46. Once again this is larger than $\alpha = 0.05$ and so there is no statistical difference between the two mean Bowling Indices for New Zealand.

To summarise, only the Batting Indices for England produced a statistically significant difference between accounting for matches played in England and considering all games played. Therefore, the country-specific Batting Index for the England batsmen is more useful in determining how well they should have played in the match. As a result, this data is used as the Expected Batting Index for England. Otherwise, in the cases where the difference is not significant, either dataset can be used. As the size of the career dataset will be either equal to or larger than the country-specific data, the averages will be equally or more representative of how well the player has performed. Therefore, in these cases, the career statistics are preferred.

4.4 Performance Index

Using equation (4) and (5), along with the Expected Batting/Bowling Indices outlined above, the two Performance Indices are found for each team:

Table 9: Batting and Performance Indices for England

Player	***Match Batting Index***	***Expected Batting Index***	***Performance Index***
J Roy	1445	5327.04	0.27
J Bairstow	2356.2	6320.27	0.37
J Root	163.31	4650.91	0.035
E Morgan	368.1	4351.62	0.085
B Stokes	7199.64	4457.01	1.6
J Buttler	5801.47	5793.47	1.001
C Woakes	100	2297.94	0.044
L Plunkett	1000	2754.70	0.36
J Archer	0	268.03	0

Table 10: Batting and Performance Indices for New Zealand

Player	***Match Batting Index***	***Expected Batting Index***	***Performance Index***
M Guptill	2005.45	3697.16	0.54
H Nicholls	3928.1	2764.57	1.4
K Williamson	1698	3939.28	0.43
R Taylor	725.7	3993.44	0.18
T Latham	3944.24	2641.15	1.50
J Neesham	1444	3130.06	0.46
C de Grandhomme	914.24	3078.23	0.30
M Santner	277.75	2387.77	0.12
M Henry	800	1576.72	0.51
T Boult	50	706.58	0.07

Table 11: Bowling and Performance Indices for England

Player	Match Bowling Index	Expected Bowling Index	Performance Index
C Woakes	222	1015.29	4.6
J Archer	2520	735.27	0.29
L Plunkett	280	925.85	3.3
M Wood	2940	1635.10	0.56

Table 12: Bowling and Performance Indices for New Zealand

Player	Match Bowling Index	Expected Bowling Index	Performance Index
M Henry	2400	763.86	0.32
C de Grandhomme	1500	2383.74	1.6
L Ferguson	333.33	748.21	2.2
J Neesham	200.67	973.90	4.9

4.5 Team Performance Index

Finally, taking the mean of the Performance Indices:

For England:

- $MPI_{bat,ENG} = 0.420781$
- $MPI_{bowl,ENG} = 2.18198$

For New Zealand:

- $MPI_{bat,NZ} = 0.552225$
- $MPI_{bowl,NZ} = 2.251342$

Now plugging this into (7) with $n_{bat,ENG} = 9,\ n_{bowl,ENG} = 4,\ n_{bat,NZ} = 10,\ n_{bowl,NZ} = 4$

$$\boldsymbol{England\ Performance\ Index} = \frac{9 \cdot 0.420781 + 4 \cdot 2.18198}{9 + 4} = \mathbf{0.963}\ (3\ s.f)$$

$$\boldsymbol{New\ Zealand\ Performance\ Index} = \frac{10 \cdot 0.552225 + 4 \cdot 2.251342}{10 + 4} = \mathbf{1.04}\ (3\ s.f)$$

5. Conclusions

5.1 Results

A Team Performance Index of one would indicate an expected performance by a side. Therefore, it can be concluded that New Zealand outperformed expectations, whereas England underperformed theirs. Hence, by this metric, New Zealand should have been declared the winner of the 2019 World Cup.

5.2 Discussion

Interestingly, this result is different to that observed in the actual game which was decided via the boundary count rule. The method produces a figure that encompasses the overall performance of a team rather than arbitrarily taking the number of boundaries scored. The rule does not consider the bowling performance of the team and a batsman could score lots of runs at a high strike rate without hitting many boundaries.

Following the criticism of the boundary count rule, the International Cricket Council (ICC) removed the rule in favour of another Super Over should the first one be tied, and subsequent ties would result in more Super Overs [12]. Whilst this would eventually end with a result, potential practical issues rise from having multiple Super Overs. For example, it would prolong an already lengthy ODI game, which takes 5+ hours to complete, and would have to be called off should the playing conditions become dangerous due to the weather. Moreover, it would only help determine which team would have better stamina, as substitutes are not allowed to bat or bowl. Hence having a metric by which the match can be decided following a tied Super Over would still have some practical use in future games.

Other methods of deciding winners used in cricket such as the Duckworth-Lewis-Stern method (DLS) [13] are only useful during the match to adjust the target score. These methods have little use in finding a winner after scores are already tied.

However, there are possible limitations with using the TPI to decide tied matches. For instance, the method will probably mean very little to the average cricket viewer who may find it too complicated to understand. They might want a more accessible way of determining the winner. During a cricket game, most of the relevant data, such as batting/bowling averages, are already presented by cricket statisticians working in live coverage. Therefore, calculating Bowling/Batting Indices as the match is happening should be straightforward. However, some of the relevant analysis, such as in section 4.3, would have to happen after the match is completed. This process could be rather cumbersome when viewers and players alike will want to know the result as quickly as possible. Also, there is the possibility that both teams could have a similar TPI. Here it is important to establish to what precision the TPIs should be compared to. Assuming the three significant figures ruling used in this paper is applied, in the unlikely case where the TPI is the same for each team, there would be no choice but to do another Super Over to produce a tangible result. It is imperative to note that the method shown in this paper only seeks to provide a more sensible alternative to the boundary count rule and is **not** a perfect solution that would work in every scenario.

Lastly, the Performance Indices shown in this paper can have uses outside of deciding the winner of a tied game. For example, it could be used by coaches or analysts to track how well a player or the whole team have performed over a certain period, or to see how the batting or bowling performances of a team compare.

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