Winning at Cricket: How Game Theory Influences Team Tactics and Player Mindsets?

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Abstract: Game theory offers a structured framework for analyzing strategic decision making. This paper is trying to examine strategic decision-making in cricket, where both the teams aim to maximize their outcomes in a competitive environment. By examining payoffs, probabilities, and opponent strategies, we investigate the interplay between possible risk and reward, bolstering to more informed and effective tactics in the match.

Keywords: strategic decision, cricket, pay-offs, risk

1. INTRODUCTION

Life is a game, and like in games, strategy and decisions define the outcomes we create."

– Albert Einstein

Game theory offers a robust framework for understanding strategic interactions across in diverse contexts, from economics to sports. In the context of uncertainty of outcome hypothesis, Rottenberg (1956) argued that unpredictability and competition are essential to the appeal of games, where the decisions of participants directly impact the outcomes. The theory has been further developed by Cain et al. (2005), Malcolm (2013) emphasizing how uncertainty at different levels viz., match, season, or championship impacts both engagement and competition.

This paper focuses on the modelling of strategic interactions in a sport like cricket, where the possible outcomes are significantly determined by the choices made by bowlers and batsmen. Fielders also play a crucial role; however, this study simplifies the analysis by concentrating on the interactions between the bowler and the batsman. These interactions are examined utilizing a game theoretic approach, particularly through a two-player one-shot game represented by a bi-matrix (2×2) framework in a competitive environment of a cricket match. Building on the core principles of game theory, this study aims to explore and justify its application in cricket by introducing a risk factor, reflecting the inherent uncertainties during a match.

This study is trying to address the following research question: What are the optimal strategies adopted by players i.e., both the bowlers and batsmen, excluding fielding influences, to maximize their chances of winning in a cricket match in a competitive environment? To put it simply, what should the optimal response to each other's actions to achieve an optimal competitive advantage.

The rest of the paper is organized as follows: Section 2 provides some background and context. Next section presents our proposed model setup. Section 4 provides the proposed solution applying several cases, and the last section concludes with some key takeaways.

2. BACKGROUND AND CONTEXT

2.1. Cricket and its rules

Cricket is a fascinating sport and has gained increasing popularity in recent years. Cricket is a sport played between two teams, each consisting of eleven players. The primary objective is to score runs from the batter side, while dismiss the opposing batsmen when fielding. The sport is typically played on a circular or oval-shaped ground, positioning a central pitch measuring 22 yards (20.12 meters) in length and 10 feet (3.05 meters) in width. The boundary of the field is marked by a rope, that determines score (either four or six) when the ball crosses it. Figure 1 displays a 22-yard cricket pitch.

Cricket is played in various formats viz., ODI (50 over match), T20 (20 over match), T10 (10 over match), Test match (five-day games where each team plays two innings). There are few other additions in recent times, including Ice Cricket (typically played on ice with 8 or 10 overs per side), Road safety matches, primarily involving retired international cricketers.

The bowler delivers the ball from one end of the pitch, while the batsman (known as striker) positioned at the opposite end, attempts to hit it. There is another batsman (non-striker) waiting at the bowler's end. A run is scored when the striker hits the ball and both batsmen manage to run to the opposite ends, exchanging positions after crossing the white line.

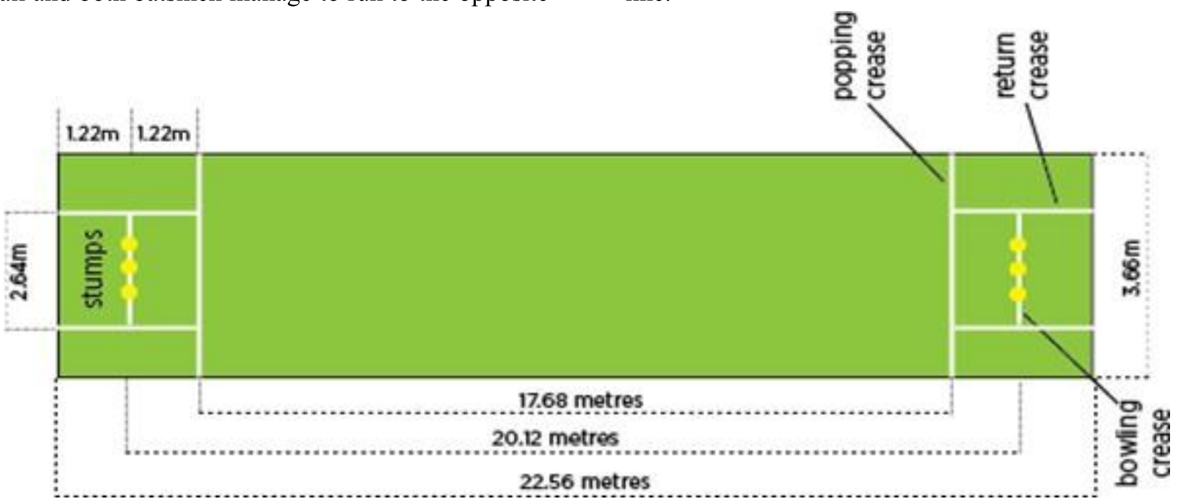

Figure 1. A visual representation of a 22-yard Cricket pitch.

The bowler employs different delivery strategies for each batsman, and the delivering strategies are different for the different respective batsmen made by the bowler. The batsman maximizes their utility by scoring more runs by taking more singles and doubles and by lofting more boundaries in terms of fours and sixes. Here we refer to it as pay-offs. Conversely, bowler maximizes their utility by minimizing the score of the opponent team and getting more wickets. Therefore, the objective of the batting team is to maximize runs scored under a certain constraint of 10 wickets. There are several ways a batsman can be given out or dismissed. Following are the different ways a batsman can be given out according to the rules of cricket:

Bowled: According to cricket rules, if the ball is bowled and hits the striker's wickets, then the batsman is given out (as long as at least one bail is removed by the ball). It is irrelevant whether the ball has touched the batsman's bat, gloves, body or any other part. However, the ball is not allowed to have touched another player or umpire before striking the wickets.

Caught: Cricket rules stipulate that if a batsman hits the ball or touches the ball at all with his bat or hand/glove holding the bat, and if the fielders, wicket keeper, or bowler catch the ball on the full before it bounces, then the respective batsman can be declared as caught out.

Leg Before Wicket (LBW): This dismissal states that if the ball is bowled and it hits the batsman on pad without the bat making contact, it is then considered as an LBW. However, for the umpire to give decision, they must evaluate several factors outlined in the cricket rules (viz., pitching inside or outside, ball tracking properly, if there are noises during the ball tracking and so on). If any of the team is not satisfied with the umpire's decision, they can appeal for review, which should be solely decided by third umpire based on some computerised exercises.

Stumped: Stumping states that a batsman can be given out if the wicketkeeper puts down the wicket while the batsman is out of his crease.

Run-out: It states that a batsman is declared as out if no part of his bat or body is behind the popping crease while the ball is in play, and wicket stumps are fairly put down by the fielding team.

Hit wicket: If a stricker knocks his wicket rather behind stumps down with his bat or body after the bowler has entered his delivery stride and the ball is in play, he or she is given as out.

Obstructing the field: This kind of dismissals states that batsman to be given out if he willingly handles the ball with the hand.

Timed out: This dismissal is to some extent interesting. If an incoming batsman is failed to arrive at the ground within three minutes of the previous dismissal, the incoming batsman will be given timed out.

Apart from these, there are many other soft dismissals in cricket rules, however this study highlights some key dismissals.

3. MODELLING OF THE GAME

This section provides the modelling of the game. The interaction between a strategic batsman and a strategic bowler can be modelled as a simultaneous move game. Firstly, the bowler can decide where to deliver on the pitch, while the batter (stricker) can decide which shot to play after the ball drops to achieve the desired outcome. We now classify the bowling strategies based on some assumptions. Bowlers are mainly classified into two categories viz., fast bowler, and spinners. Nevertheless, the study focuses solely on fast bowling strategies disregard spin actions to make our model simple. The simplest form of strategic interdependence prevails in contexts in which the actions are taken simultaneously. To model such a scenario, we need to specify the set of interacting individuals usually referred as players of the game, and their respective actions. The strategic form of the game can formally be defined as follows:

Let, Set of players: N

A set of actions: $A = \times_{i \in N} A_i; \forall i$

A pay-off function: $u_i: A \to R; \forall i$

Where: $i = 1,2, \dots, N$.

Case-I: Here in this study, $N = 2$. Both the batsman and the bowler have their available strategies. In order to analyze the normal form of this simultaneous move game, we identify the optimal strategies, assuming each player should choose to win this one-shot game i.e., only a single delivery is considered here. The strategy sets for each player can be defined as follows:

$$A_{bat} = \{Attack, Defend\}$$

$$A_{bowl} = \{Attack, Defend\}$$

Both the batsman and the bowler adopt two strategies: attack and defend. For ease of understanding, the study considers delves into a hypothetical example. The pay-offs for a 2×2 game table are as presented in table 1 as follows:

Table 1. Player strategy rankings from best to worst

Batsman	Bowler
$Attack$ (2)	$Attack$ (1)
$Defend$ (1)	$Defend$ (0)

We now form an extensive-form game tree to show the above situation. Figure 2 visualises the game tree of an Extensive-form game. Here in this study, bowler is the first mover, after watching the move made by the bowler the batsman decides to move and the information is complete.

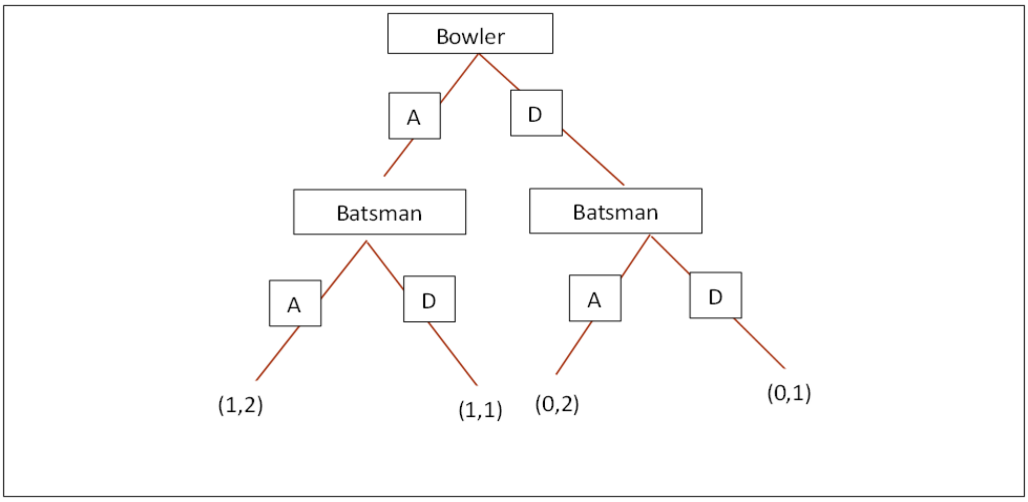

Figure 2. Game Tree of an Extensive-form game

If we construct this extensive form game in a normal form game, the game table can be as follows (see table 2):

Table 2. Normal Form game representation with payoff values

Bowler \ Batsman	Attack	Defence
Attack	(1,2)	(1,1)
Defence	(0,2)	(0,1)

Note: Here the bowler is the row player and the batsman is the column player

Now we find out the optimal strategies adopted by both players from table 2, that are derived through the interactions of the best response function. Best response functions are defined as one from where the players don't have any incentive to deviate. In this case, the possible Nash Equilibrium (NE) is (A, A) i.e. both the players have to impose their best strategy 'attack' for winning the game. So, (A, A) is the NE, and the corresponding pay-off is $(1, 2)$. Therefore, the NE outcome: $(A, A) = (1,2)$.

Case-II: In this case, the above game can be modelled in an alternative approach for analyzing the possible strategies. This technique helps to better understand the dynamic interactions between the players. Table 3 illustrates the normal form game with some probabilities of different outcomes or actions, often incorporating randomization in their strategies.

Table 3. Normal form game with associated probability

Bowler \ Batsman	Attack	Defence
Attack	π_{AA}	π_{AD}
Defence	π_{DA}	π_{DD}

Note: Here the bowler is the row player and the batsman is the column player; π is the pay-off of probability of success.

Case-III: This case now incorporates the possible risk factor associated with the pay-offs. Let, φ be the risk component, and risk is basically the probability of occurrence of an unwanted event multiplied by the consequence (loss) of the event. If we define probability as p and the impact factor as ω, then risk can be measured as:

$$\varphi = p\omega$$

i.e., risk = probability x impact. Table 4 depicts the above-mentioned normal form game with risk component φ associated with the payoffs.

Table 4. Normal form game with possible risk component

Bowler \ Batsman	Attack	Defence
Attack	φu_{AA}	φu_{AD}
Defence	φu_{DA}	φu_{DD}

Note: Here the bowler is the row player and the batsman is the column player; φ is risk component

Case-IV: In this case, we specify the delivery strategies employed by the bowler, and outline the shot selection employed by the batsman. Here both the players have three strategies. The strategies are as follows:

$$A_{bowl} = \{Yorker, Knuckle, Bouncer\}$$

$$A_{bat} = \{Attack, Short\ run, Defence\}$$

We now rank their strategies from best to worst:

Table 5. Player rankings from best to worst for three alternative strategies

Batsman	Bowler
$Attack\ (1)$	$Yorker\ (3)$
$Short\ run\ (0)$	$Knuckle\ (2)$
$Defence\ (-1)$	$Bouncer\ (1)$

We are now trying to build up an extensive form game tree to analyze the situation. In this case (see figure 3), the bowler is the first mover, and after watching the move made by bowler the batsman moves. Here the information is of a complete nature.

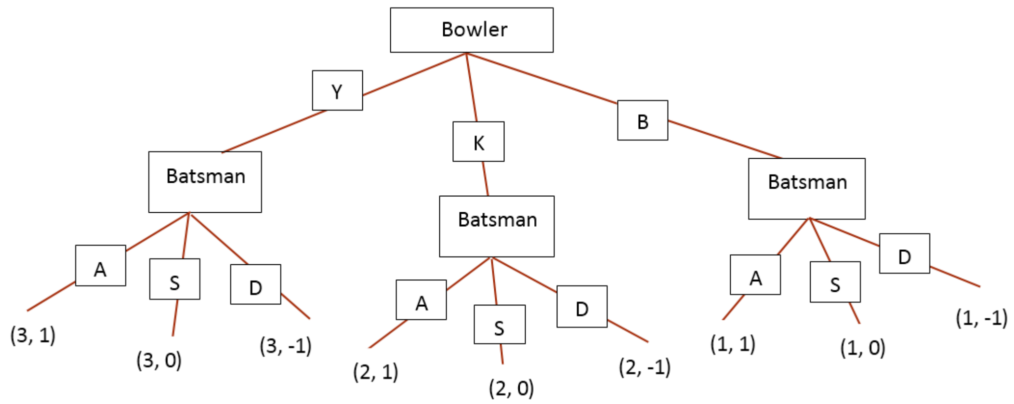

Figure 2. Game tree representation with three strategies

The study now determines the Sub-game Perfect Equilibrium (SPE). The SPE differs from the NE. There are six sets of possibilities: $(AAA, ASA, SAA, SSA, DAA, DSA)$. The SPEs are $i.(Y, (AAA), Y(ASA), \ldots, (Y, (DSA))$. In a similar approach we can determine for all the SPEs. This extensive-form game can be modelled in a normal form game as:

Table 6. Normal Form game representation with two players and three strategies

Bowler \ Batsman	Attack	Shot	Defence
Yorker	π_{YA}	π_{YS}	π_{YD}
Knuckle	π_{KA}	π_{KS}	π_{KD}
Bouncer	π_{BA}	π_{BS}	π_{BD}

Note: Here the bowler is the row player and the batsman is the column player; π is the pay-off values

The study now considers a hypothetical approach to identify the NE of the game, aiming to determine the optimal strategies made by the rational players.

Table 7. Normal Form game representation with payoff values

Bowler \ Batsman	Attack	Shot	Defence
Yorker	$(3,1)$	$(3,0)$	$(3,-1)$
Knuckle	$(2,1)$	$(2,0)$	$(2,-1)$
Bouncer	$(1,1)$	$(1,0)$	$(0,-1)$

By solving the game, we obtain a NE. Here, in this case (Y,A) representing the NE outcome, and the corresponding pay-off is given by $(3,1)$. Indicatively, $(Y,A) = (3,1)$

It asserts that both players will choose their best responses to maximize their desired output i.e., the bowler will opt their optimal strategy by executing a yorker delivery, while the batter will attempt an aggressive lofted shot to claim victory. However, if we model this scenario into an extensive-form game, the strategies may differ.

4. CONCLUSION

In this study, we explored a game theoretic approach trying to model strategic interactions between a bowler and a batsman in a competitive environment of a cricket match. By simplifying the study to a two-player (bowler and batter) one-shot interaction, representing through bi-matrix (2×2) game, we have analyzed the optimal strategies taken by both the players. Exclusively, the bowler aims to maximize the probability of dismissing the batsman, while the batsman seeks to optimize scoring opportunities through high-risk lofted shots. This dynamic accentuates the essence of strategic decision-making under uncertainty, a key aspect of cricket's gameplay. Through the inclusion of risk and uncertainty in our study, we utilize the pertinence of Nash Equilibrium and Subgame Perfect Equilibrium (SPE) as a probable solution concept to determine the optimal strategies for both players.

Overall, this study establishes a fundamental outline for analyzing strategic interactions in cricket through a game-theoretic lens. Here we primarily focus on two-player interaction, future work could incorporate multi-player interaction at the same time, including fielders. Furthermore, empirical validation remains a crucial step in justifying theoretical findings. By analyzing data, we seek to evaluate the real-world applicability of our proposed model and refine its predictive precision.

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