Examining NBA Crunch Time: The Four Point Problem

Andrew Burkard
Dept. of Computer Science
Virginia Tech
Blacksburg, VA 24061
aburkard@vt.edu

Abstract

Late game situations present a number of tough choices for NBA coaches and players. Proper decision-making is even more important when a team is trailing by multiple baskets. We examine one particular question: should a team down 4 near the end of a game shoot a 2 or a 3? Also, how should the defense respond? By building a game model and comparing the results with analytical research, we find that conventional wisdom regarding the “easy two” is generally correct. Defenses will do their best to prevent 3 –point shots at the expense of allowing easy 2’s. It may be to the offense’s advantage to take the easy 2 when presented, provided they have enough time left to run another possession.

1. Introduction

Ask any basketball fan why their team lost a close game, and they will probably blame the referees. Failing that, they will aim their venom at the coaching staff. At the end of close games, individual coaching decisions such as offensive/defensive strategy, timely fouling, and clock management can have substantial impacts on the outcome of a game. These situations are commonly referred to as “crunch time” or “the clutch”. Conventional wisdom holds that some players and/or teams are able to raise their game and perform better in these situations than they otherwise would while others are known to choke under the pressure. Just how much basis there is to any of these claims is the subject of much debate in the statistical community. One view is that clutch performance is mostly an illusion caused by an overreliance on small datasets (Silver, 2007). However, there is evidence that in close, late game situations, the efficiency gap between the best and worst NBA offenses and defenses is actually wider (Goldman and Rao, 2013).

Although the manta “2 points is 2 points” is as true as any tautology, the zero-sum nature of basketball implies that a team will try its hardest when a game is up for grabs. Consider that a made free throw for a team trailing by 2 can increase their probability of winning by 10 times as many points as it would in the median situation (Goldman and Rao, 2012). Although both events have the same nominal value, the fact that the reward (a win) is ascertainable by both teams makes the shot appear to carry more weight. Now surely, there would be no gain or loss felt by trading one point in the second quarter of every game for a point in the fourth quarter of the same game. However, it could be advantageous to trade a point (or more) in tomorrow's point for a game in today's game if the change in expected win probability indicates so.

For this reason, as well as the avoidance of media criticism, it is crucial for a coach to practice optimal decision making in crunch time. Fortunately, the abundance of timeouts, commercials, and official reviews present in the modern NBA allow a coach many opportunities to talk strategy with his players. Our goal is to examine the optimal decision for a particular situation, the two-possession game.

2. Problem Background

A two-possession game describes a state of the game in which the trailing team would need to gain possession of the ball twice to be able to even the score. In pro basketball there are shots valued at 2 and 3 points. Thus, a situation where the point differential is 4, 5, or 6 points would be considered a two-possession game[1].

At most times during a game, the win probability for one of the participants follows a logistic function of the score difference (Burke, 2009). That is, the difference in win probability between a 3-point game and a 4-point game isn't wholly different from that of a 4 and a 5-point game. However, as the clock ticks down and the number of remaining possessions decreases, the number of points possible on those possessions begins to take on greater meaning. This is partly a function of the game clock: consider the difference between a 3-point game and 4-point game where you have the ball with 2 seconds remaining. But is also a result of the shot clock, or rather the length of it. In the NBA, the shot clock is 24 seconds. If a team fails to shoot within this timeframe, they lose possession of the ball. In a two-possession game with less than 24 seconds remaining, the leading team is able to run out the clock by not shooting the ball. To prevent this, the opponent must attempt a steal, or as is usually the case, intentionally foul. This results in two free throw attempts and a change in possession, failing an offensive rebound. It is incumbent upon to keep playing this strategy until they either even the score or the game ends.

In this paper, we take a look at two-possession games where the score difference is 4-points and the game clock is at 24 seconds or less. We will consider only those situations where the trailing team begins with the ball. The questions we are looking to answer are: on the first possession, should the trailing team shoot a 2 or a 3? And how much attention should the defense give to defending each type of shot? It is unlikely that there is any absolute answer to either question. As in many sports or even games in general, the best option is to vary one's play. For this reason, we seek to find a mixed-strategy Nash equilibrium for the offense's shot selection and the defense's attention. We will do this by running repeated simulations on a self-constructed model. These results will then be compared to the actions of actual NBA teams in the same situations.

[1] Technically, events such as 4-point plays are possible. However, since they are a rare occurrence, and the offensive team has little control in generating them, we still

3. Model Description

We model end of game basketball situations as a competitive two-player zero-sum game. Let us begin with some specifications:

Def.

- Players: Home (H), Away (A). At each stage of the game one team is designated the offensive team, the other is on defense.

- States: $S = (\text{Home Lead}, \text{Time Left}, \text{Possession})$ where Home Lead and Time Left are integers representing the score difference and the time remaining on the game clock, and possession is either Home or Away.

- Action space: Offense: $O = \{2,3\}$, Defense: $D = \{\text{Low}, \text{Med}, \text{High}, \text{IF}\}$. At every state, the offensive team may opt to shoot a 2 or a 3. The defense chooses how tightly they guard the 3-point line, which has the opposite effect on how tightly they guard against a 2-point shot. Additionally the defense can opt to intentionally foul.

- Transition function $T: S \times O \times D \to \Delta(S)$ maps each state and offensive/defensive action pair to a probability distribution over states $\Delta(S)$. Most of the values in the distribution will be 0, as the only possible states are those where the shot goes in, or the shot misses (excluding intentional foul cases).

- Initial State: $s_0 = (4, t \leq 24,\ \text{Away})$. As previously mentioned, we only consider games where the point differential is 4 and we begin in the last 24 seconds. We designate the "Away" team as the team initially trailing, although this designation is merely superficial. There is no home court advantage or disadvantage.

- Reward Function: $R: S \to \{-1,0,1\}$. Each player's reward is a win, loss, or draw, depending on the value of Home Lead when $t = 0$.

- We will refer to the home away teams' action set at state s as $A_a(s), A_h(s) \in \{O, D\}$

The most striking feature of the model is the order or lack thereof in which offenses and defenses act. On every turn both the offensive and defensive team must make a decision as to which action they should take. They must do so simultaneously. Now, one could argue that on a single possession, both teams are constantly taking many actions and constantly responding to actions taken by the other team. Unfortunately this behavior is far too hard to model. We take the view of a coach who has just called a timeout. He has no way of knowing which action the other team will take although he is aware of the available actions for both teams. His goal is to choose the action that will give his team the best chance to win.

This begs the question of how to determine which action gives us the "best chance to win", i.e. the highest win probability. Fortunately for us, we possess the computational power to play out the entire game tree. At each step an agent (coach) forms an estimate of which action the other team will take based on learned data from previous simulations. For each of its potential actions, the agent estimates the win probability of taking that action:

$$WP_a(s,a) = \sum_{h \in A_h(s)} \left[\sum_{s_i \in S} \left(max_{a_i \in A_a(s_i)} WP(s_i, a_i) \right) \cdot T(s,a,h)_i \right] P(h)$$

Here, we have the win probability function for the away team when choosing action a in state s. It is simply the sum of the win probability of each possible transition state multiplied by the probability that we end up in that state, all of which is dependent on the home team's action. In essence, we are playing our way down the game tree. We assume at each step that the opponent is acting rationally and is also trying to maximize its win probability. Note that the estimated action probabilities for the other team are simply the proportion of times the opponent took that action in previous simulations.

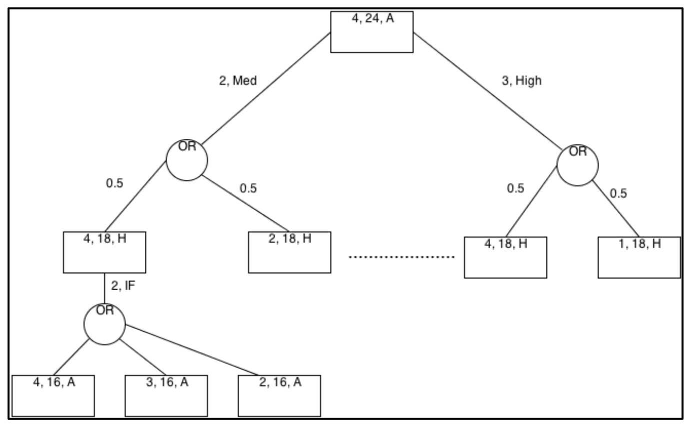

Figure 1: A simplified game tree showing the stochastic nature of transitions. Note that all aspects of a state: score, time, and possession transition stochastically

As for how transition probabilities are calculated, the key here is in NBA play-by-play data. For instance, the offense's shot choice and the defensive pressure determine the probability that a shot attempt is successful. The way this is done is through a linear function between the best-case and worst-case probabilities for the chosen shot type. I did my best to estimate these values by looking for certain situations in play-by-play data. For instance, a 3-point game with a few seconds left provides a good estimation of how likely a team is to make a 3-pointer when the defense has chosen high pressure on the 3. Likewise it presents the best-case probability for a 2-point shot, as the defense will likely put little to no effort into protecting the basket.

Other transition parameters such as time and possession are also estimated through this method. A very important characteristic of this problem is that 2-point shots generally take less time to generate than 3-point shots, as teams feel the potential reward of a 3 is worth working for. In general, the more the offense's action and the defense's pressure on that action are aligned, the longer the play will take. Offensive rebounds are also a consideration. Conventional wisdom holds that 3-point shots are easier to offensively rebound. However, truth of this assertion is subject to debate (Oliver, 2004). For our purposes, we assume that all shots are equally likely to generate offensive rebounds.

4. Results

We run 1000 simulations each with various starting time values between 10 and 20 seconds.[2] At the start of each game, the away team has the ball and is trailing by 4 points. It is tasked with determining the best action at that time period. Each agent has knowledge of the other agent's action history within the simulations that begin at the same time period. This is analogous to an NBA coach having scouting history of another team's tendencies, albeit a very robust scouting report. First we look at how often teams opt to shoot the 3 or go for a quick 2.

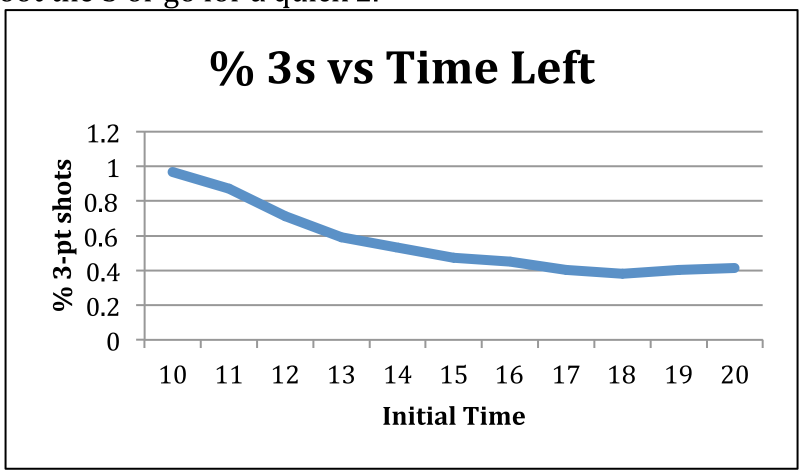

Figure 2: Teams preference for 3's decreases when they have more time

We find that as the amount of time remaining on the clock on the beginning of the simulation decreases, the away team's preference for 3-pointers increases. This result aligns with the theory that as time remaining decreases, a team's preference for risk should increase (Goldman and Rao, 2013). What's fascinating is that even though the offense knows the defense is going to defend the 3 heavily, they still prefer it, as it is their only chance of winning. On the other end of the spectrum, even when the offense's preferences are such that they mostly shoot 2's, the defense still opts defend the 3-point line. This is consistent with the idea that defenses in this situation will opt to give up the easy 2 so that they may prevent the offense from shooting a 3.

[2] Smaller values gave bad results due to probabilities being crushed by loss of precision. Larger values proved computationally infeasible, although any values above 24 need not apply anyway.

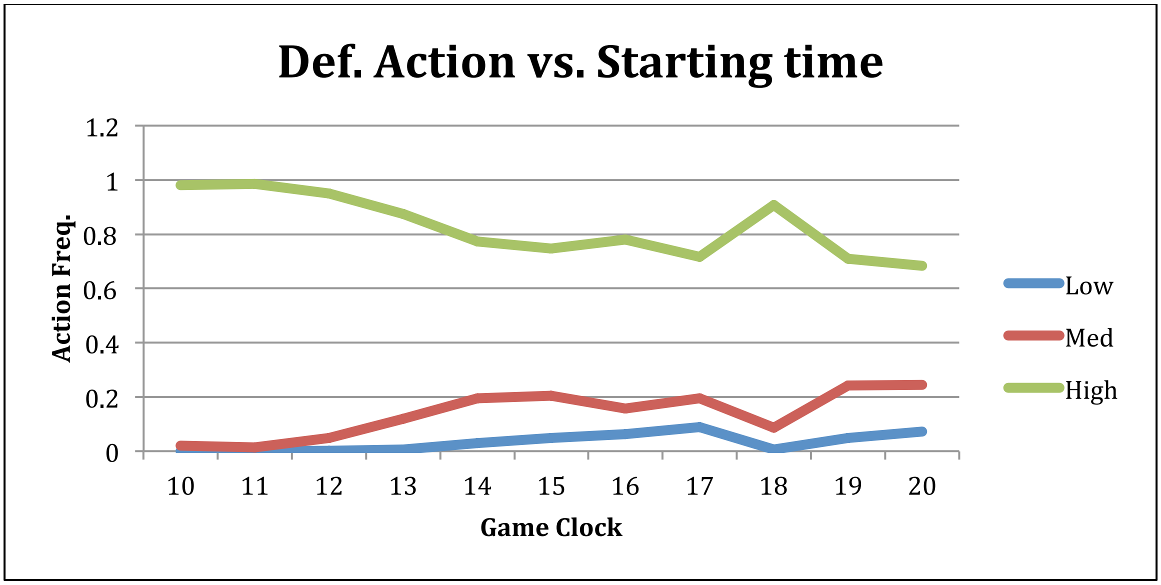

Figure 3: More often than not, teams guard heavily against the 3. However, they do adjust somewhat for the times when the offense is more likely to shoot 2's.

Another concern is just how much the time remaining affects how likely a team is to win a game. For our purposes, we assume there is little control over how long it takes to generate a shot, besides the selection of which type of shot to shoot. However, in a real game a coach may want to know how much time he should be willing to trade for a chance at a better shot attempt. We can estimate this by looking at how likely the road team is to win against how much time is on the clock at the initial state. Note that for our purposes, the teams are considered evenly matched. Thus all tied games are considered equally likely to be won by either team in overtime. We find that there appears to be some positive relationship between the amount of time left on the clock and the win probability of the trailing team. However, the relationship much noisier than it was for 2/3-point shot preference. This question basically boils down to whether or not a team has time to conduct two possessions. For initial times lower than 5 seconds, the win probability was effectively 0, as it is highly unlikely a team can get off two quality shots and an intentional foul in that timeframe.

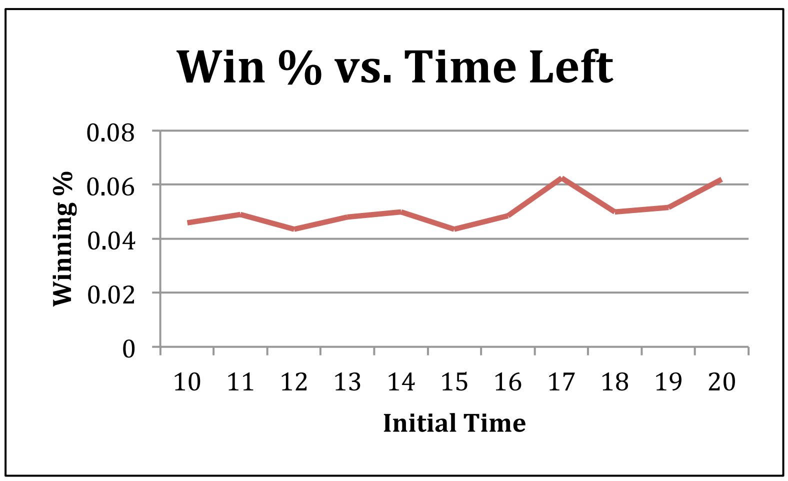

Figure 4: When there is a moderate amount of time left on the clock, there is not a very strong relationship between win probability and time left.

5. Analytic Results

Although the model gave results that seem to line up with preconceived theories on crunch time decision-making, it is imperative that we compare these results to data gleaned from actual NBA games. We use NBA play-by-play data from the year 2006-2012[3] to examine the results actual decisions made in 4-point games.

	2pt FG%	3pt FG%
General	.484	.365
Down by 4, Last 24 seconds	.574	.203

Figure 5: Mean efficiency in all situations compared with in 4-point games. The difference is statistically significant ($p < 0.001$)

The data show that in these situations, teams become more efficient at converting 2-point attempts, but less efficient when shooting 3's. This fits with the results of the model simulation that show teams being willing to give up 2-pointers in order to prevent 3-point shots.

Of additional interest is how well teams shoot at different periods in the game clock. Unfortunately, there is not enough data to get reliable values for each second on the clock, so we decided to bin the values. We can see that teams tend to have a larger gap in 2 and 3-point efficiency in those midrange 10-20 values. As we saw before, this is when defenses are willing to give up the 2.

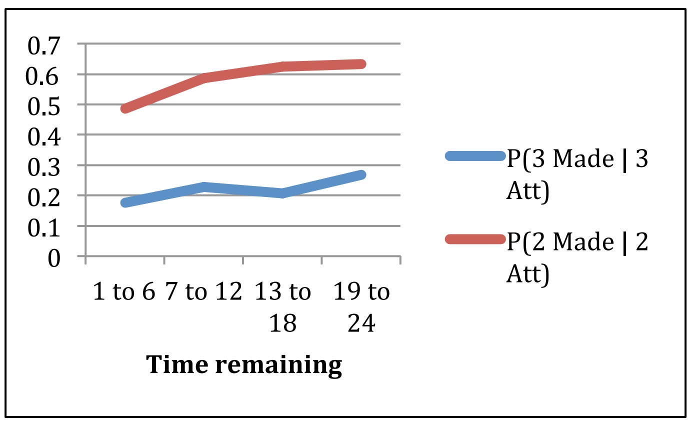

Figure 6: Shot probablities in 4 point games

[3] Data before the '06-'07 season doesn't state when 3 point shots are missed, so it is of no use. Also, rule changes implemented before the '04-'05 may have some effect on previous years.

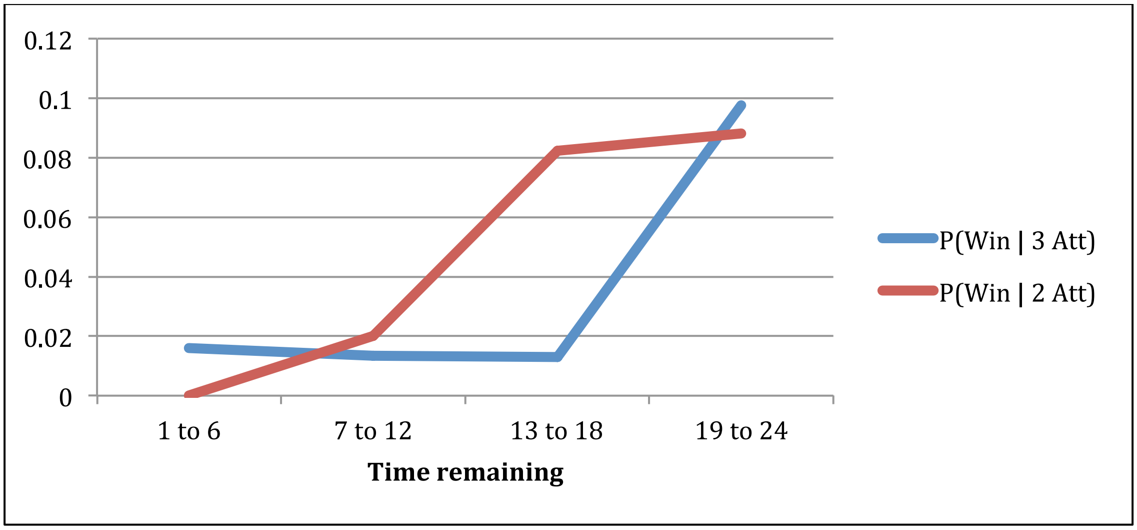

Figure 7: Win probability given the chosen shot is attempted on the first possession of a 4-point game

Of course, the most important question we have been asking is which shot gives a team the best chance of winning, 2 or 3. Well, here the answer can be a little fuzzy. We see in the graph the 2 point shot attempts tend to be preffered in the midrange time values. However, the amount of data is so little[4] that it is hard to say with much confidence that teams should be shooting more 2's. Also, these are win probabilities for the average shot. The values for the marginal 2 or 3-point shot might be different.

6. Conclusions

The results of the simulation model, along with data gleaned form NBA games suggest that defense's will alter their behavior to prevent 3-point shots at the expense of allowing easy 2-pointers near the end of 4-point games. In these situations, it is generally to the offense's advantage to increase their preference for riskier 3-point shots as the clock ticks down. More time on the clock is generally favorable to the trailing team. However, when there is enough time remaining to conduct two possessions, it may be in their best interest to get the best shot possible.

[4] 876 total instances between 0 and 24 seconds, 357 of which are in the last 6 seconds

References

Burke, Brian. "Modeling Win Probability for a College Basketball Game." Web log post. *The Wages of Wins Journal*. The Wages of Wins Journal, 5 Mar. 2009. Web.

Goldman, Matt, and Justin M. Rao. "Effort vs. Concentration: The Asymmetric Impact of Pressure on NBA Performance." Proc. of MIT Sloan Sports Analytics Conference 2012, Boston, MA. N.p., 1 Mar. 2012. Web.

Goldman, Matthew, and Justin M. Rao. "Live by the Three, Die by the Three? The Price of Risk in the NBA." Proc. of MIT Sloan Sports Analytics Conference 2013, Boston, MA. N.p., 1 Mar. 2013. Web.

Oliver, Dean. "Rebounding Myths and Roles." *Basketball on Paper: Rules and Tools for Performance Analysis*. Washington, D.C.: Brassey's, 2004. N. pag. Print.

Silver, Nate. "Is David Ortiz a Clutch Hitter." *Baseball between the Numbers: Why Everything You Know about the Game Is Wrong*. New York: Basic, 2007. 14-34. Print.