CLUTCH SHOOTING PERCENT (CSP): A MEASURE OF PLAYER'S CLUTCH PERFORMANCE DURING A GAME AND MATCH

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ABSTRACT. The aim of this paper is to describe and list a new Pool Stats metric, which we call a sabermetric, after the notion that was introduced to the sport of baseball by Bill James. We define 'clutch' to mean a player's performance under adversity and executing the shots needed to seal a victory. Similarly, a player's match 'clutch' performance is the average performance throughout each game. That is to say, if the player performs stronger toward the end of the match the overall CSP will reflect that. We will outline our formula for CSP and CSP-Match (CSPM) and give some brief calculations and examples to give the reader an idea of the values CSP produces. The values of CSP are calculated within the Pool Stats Pro app and are available in the app and on the Pool Stats Metabase interface.

1. Introduction

One can find many useful applications to a metric which illustrates a player's clutch performance. It can help illustrate how well a player handles the beginning, middle, and endgame. It can also depict the level to which a player may be able to run the rack after facing certain defeat. The averages of a player's CSP throughout the match will show, if graphed, how well a player performs 'in the clutch' toward the end of the match.

This stat originated in the NBA [1] as a way to gauge the performance of a basketball player in the final 5 minutes, 1 minute, and 24 seconds of a game. We adapted it toward the game of pool, not solely based on the last few balls made, as would be analogous to the NBA, but over the course of the entire game and match. The reasoning behind this is to show how well a player can run-out or break-and-run a game which is a grave illustration of a player's clutch performance in the cue sports.

More value is given, such as in the case of an eight-ball game, to the ability of the player to win the game when more of his opponents balls have been potted. In the case of nine and ten ball games where the opponent has potted balls, but the other player seals a victory more value is awarded to the winning player for their clutch performance when his/her opponent was on the brink of winning. The maximum CSP of 100 will be awarded when the player breaks-and-runs the rack. In the case of eight-ball, when the player's opponent has potted all their balls, missed the eight, and the player comes back to pocket his/her remaining seven balls and then pockets the eight to seal a victory a CSP of 100 is awarded to the winning player.

A detailed analysis is given in the further sections. We also present example calculations in Section 3 for the values of the CSP function.

Key words and phrases. Pool Stats, Sabermetrics.

2. Analysis

We have derived to be, what we consider, a good measure of a player's clutch performance by the means of an algebraic recurrence relation. Many equations were tested for robustness in determining a feature to highlight this aspect of a player's game. After much analysis, we arrived at a multivariate, 3-dimensional, algebraic recurrence relation.

We initially started off with the 3-dimensional equation before adding the recurrence factor. This added factor gives a nice model for a propagating clutch shooting percent, and builds as the player performs better and better. Although we call it a percentage, it is really more of a quantitative factor; however, since the maximum value of CSP is 100, we can justly use it as a percentage, where certain key values will represent a strong performance.

The CSP function has taken on new forms in recent months. Initially, we started with the 2-dimensional ratio in x and y which represented balls potted for player 1 and player 2. Finding this didn't represent certain scenarios accurately, we then started from scratch building an algebraic model, in three variables, adding to it the recurrence relation, and finally adding on a factor for shot probability. Like anything else in the statistical sciences, measuring nature with probability and statistics will always get enhancements to the general equations as more factors are needed to better represent the problem at hand.

Let us first outline the variables, starting values, and indices represented in the CSP function.

(1) p: player (i.e. PlayerID)
(2) n: iteration, $n \in \mathbb{N} - \{0\}$
(3) x: number of balls potted by p
(4) y: number of balls potted by opponent
(5) z: number of consecutive made shots by p
(6) k: type of game, $k = 8$ for eight-ball. $k \in \{8, 9, 10\}$
(7) λ_k: game scaling factor (GS)
(8) α: opponent balls made scaling factor (OS)
(9) μ: average shot probability of the set of consecutive made shots.
(10) $\tilde{Z}$: the set of consecutive made shots
(11) $\mathfrak{s}$: a particular shot
(12) $\mathscr{P}(\mathfrak{s})$: shot probability of shot $\mathfrak{s}$
(13) $\mathcal{CSP}_k^1 = 1$: CSP starting value

Equation 2.1. *General 3-dimensional algebraic recurrence relation for Clutch Shooting Percentage (CSP):*

$$\mathcal{CSP}_k^{n+1} = \mathcal{CSP}_k^{n+1}(x, y, z) = \lambda_k \left(x + \alpha y + z^2\right) + (2 - \mu) \cdot \frac{\mathcal{CSP}_k^n}{n}$$

What makes this a recurrence relation is that previous calculations of CSP are factored into it's new computations. In other words, the values of clutch shooting propagate over time, with a maximum of 100.

Equation 2.2. (μ), *Average shot probability over the set* $\tilde{Z}$

$$\mu = \frac{1}{z}\sum_{i=1}^{z} \mathscr{P}(\mathfrak{s}_i) \qquad \text{, where } \mathfrak{s}_i \in \tilde{Z}$$

Equation 2.3. (λ_k) *Game scalar (GS) for* $k \in \{8, 9, 10\}$

$$\lambda_8 = \frac{981}{860} \qquad \lambda_9 = \frac{109}{100} \qquad \lambda_{10} = \frac{981}{1100}$$

This scaling factor is important for normalizing the function to 100. The indices $8, 9, 10$ represent the games of eight-ball, nine-ball, and ten-ball respectively.

Equation 2.4. (α) *Opponent scalar (OS), or opponent made balls scalar*

$$\alpha = 2$$

We think 2 is a good scalar for the number of balls currently potted by the opponent. It works nice in the computation of the values for giving a little more aggressive approach to making balls when your opponent is near his or her endgame. It is possible that α may change in future analysis if we think a larger (or smaller) scalar will give a more decisive measure. If α changes then so will λ_k. This shows that λ_k is dependent on the values it scales.

Also we acknowledge that squaring the number of consecutive made balls, z, by player p, gives a good account for how clutch a player is shooting. As more balls are made consecutively, i.e., clutch shooting, the $\mathcal{CSP}$ value increases proportionally.

To further understand what is going on here, $\mathcal{CSP}$ values are calculated only after a player has missed their shot or played defense. Therefor after 4 consecutive made shots and the player plays defense (or misses) then $\mathcal{CSP}$ calculated within the Pool Stats Pro app.

There remain a few noteworthy mentions to our calculations. First, the starting value of $\mathcal{CSP}$ is $\mathcal{CSP}_k^1 = 1$. This is primarily so that μ, the averaging of shot probabilities over $\tilde{Z}$, is given some value on the first real calculation of $\mathcal{CSP}$. i.e., $\mathcal{CSP}_k^2$. Also, note that $\max(2 - \mu) = 1.9$ and $\min(2 - \mu) = 1.1$. This gives a upscale of the recurrence factor, based on average shot probability over the consecutive made shots.

Another noteworthy calculation is that within the Pool Stats Pro algorithm for computing $\mathcal{CSP}$ we do include a 'missed shot scalar' for computing the CSP value when a shot is missed. There is not much to this as it is simply multiplying the last calculated CSP, i.e., $\mathcal{CSP}_k^n$ by a scalar β. Expressed formally

Equation 2.5. *CSP missed shot calculation*

$$\mathcal{CSP}_k^{n+1} = \beta \cdot \mathcal{CSP}_k^n$$

where $\beta = .9$. As you can see we downscale the CSP value only slightly. However, the more missed shots a player has the greater the downscaling. Future calculations of $\mathcal{CSP}$ may have different β values. For now, we conclude this is a reasonable estimate.

Next we outline how we compute CSP-Match ($\mathcal{CSPM}$) to determine the match clutch shooting percentage for a given player. The calculation is rather straightforward as we take the maximum CSP value per game for each player and average them over the total number of games. The equation is as follows:

Equation 2.6. *$\mathcal{CSPM}$ or Match Clutch Shooting Percentage*

$$\mathcal{CSPM} = \tfrac{1}{\#G_p} \sum_{G_p} \max_{G_p}\{\mathcal{CSP}\}$$

where $\#G_p$ is the total number of games played over the match or year, as we calculated a running average of $\mathcal{CSP}$ over each year for every player. Also where G_p is the game for player p, and max is the maximum value of $\mathcal{CSP}$ for the player during that game.

Our reason for taking the maximum value for $\mathcal{CSP}$ over each game is two-fold. First, it is easier in the computations via our Metabase web portal. Second, because we believe that the maximum value of $\mathcal{CSP}$ during a game better represents a player's performance throughout the match.

3. Calculations and Examples

In this section we give some examples for eight, nine, and ten-ball games $k \in \{8, 9, 10\}$ along with some calculations of CSP. We show what parameters are needed to reach a CSP of 100 along with various game scenarios.

The following table illustrations give some example of game scenarios and CSP calculations.

Table 3.1. *Examples and calculations of $\mathcal{CSP}$*

k	n	p	x	y	z	μ	$\mathcal{CSP}_{\mathbf{k}}^{\mathbf{n}}$	$\mathcal{CSP}_{\mathbf{k}}^{\mathbf{n}}$ **w/o** $(2-\mu)$
8	1	1	8	7	8	.9	99.2	100
8	1	1	8	7	8	.1	100	100
8	1	1	1	0	1	.1	4.18395	–
8	1	2	1	1	1	.1	6.46279	–
8	2	1	2	1	1	.1	8.53754	–
8	2	2	2	2	1	.1	14.12453	–
8	3	1	3	2	1	.1	14.53269	–
8	3	2	3	3	1	.1	20.35246	–
8	4	1	4	3	1	.1	19.45070	–
8	4	2	4	4	1	.1	24.49648	–
8	5	1	5	4	1	.1	23.36103	–
8	5	2	5	5	1	.1	27.55982	–
8	6	1	6	5	1	.1	26.78952	–
8	6	2	6	6	1	.1	30.40053	–
8	7	1	7	6	1	.1	30.08539	–
8	7	2	7	7	1	.1	33.34691	–
8	8	1	8	7	1	.1	33.38123	–
9	1	1	9	0	9	.9	99.2	100
9	1	1	9	0	9	.1	100	100
9	1	1	9	0	8	.7722	80.79777	81.1111
9	1	1	9	0	7	.7722	64.44777	64.44444
9	1	1	3	0	3	.7166	14.36331	13.33500
9	1	2	2	3	2	.5750	14.50500	13.33500
9	2	1	7	3	4	.5625	41.93310	38.27750
9	1	1	5	0	4	.825	24.06500	23.33333
9	1	2	1	5	1	.1	14.98000	13.33333
9	2	1	8	1	3	.7166	35.06250	31.28665
10	1	1	10	0	10	.9	99.2	100
10	1	1	10	0	10	.1	100	100
10	1	1	10	0	9	.6142	82.54110	81.81818
10	1	1	10	0	8	.6142	67.3802	67.27272
10	1	1	3	0	3	.9	11.801818	10.90909
10	1	2	1	3	1	.5	8.634543	7.272727
10	2	1	6	1	3	.8	21.35018	19.99995
10	2	2	1	6	0	.825	7.777	6.545454
10	3	1	9	1	3	.7166	26.1066	23.93922

The cyan colored rows indicate when a victory in the game has taken place. The yellow colored rows indicate a break-and-run for different number of balls potted on the break. As you can see a CSP value > 60 indicates a run-out, with higher CSP values given to those that had to take more shots to run out.

The table gives a good standard to go by. When a player makes many consecutive shots over the smallest amount of turns taken, the CSP > 40. This gives a good measure of what a good CSP looks like. It is our conclusion that a CSP > 40 can be considered as highly clutch. 40% shooting percentage doesn't sound great, but as seen in the NBA and in [2], 40% shooting ranks players the highest, as so it does in billiards with our CSP calculations.

Given that normal shooting percent for the world's best pool players hover around $90-95\%$, clutch shooting percent will be up there when a player runs the whole rack, but as more turns are taken i.e., giving your opponent the opportunity to run-out, your clutch should be nearly halved after the first turn was given up.

Another illustration of the table is that when players trade off turns and made one shot on each turn until the game ends, yields nearly equivalent CSP values. This is a good feature of our equation, as player 2 always is behind and still produces, but with player 1 winning in the end. So, a CSP value > 33 is considered clutch, just not highly clutch.

Also, we can see the effect of taking the average shooting probability over the consecutive made shots adds a significant factor to the equation when the number of shots is low. The addition of this factor better measures a player's CSP than when we equated CSP without it. As more shots are taken by a player the CSP levels around 20 which is not clutch considering it took them longer to win the game.

For $\mathcal{CSPM}$ the values can be averaged over the games and a match clutch shooting percentage can be calculated similarly. We leave those calculations to the reader.

4. Further remarks

Currently we do not involve defensive play in our CSP calculations. Our goal was to make a relatively straightforward expression of CSP and adding defense into the mix would make it much more complicated. We are aware good safety play is part of clutch shooting, but on a lesser scale than the main factor of potting your balls to win. In the future, we will consider using our Defensive Success Rate metric within our CSP calculations to factor in strong safety play, if we find it necessary. At the current time, our CSP function strongly illustrates clutch shooting.

The nice thing about our CSP function is that it is a recurrence relation. These tend to have nice mathematical properties when algebraically manipulated. It is our hope that future mathematicians and statisticians will play around with our equation and discover nice properties that it may contain. Another thing to note is that for the game of ten-ball $k = 10$, the CSP function outputs periodic numbers which is another nice property.

The reader can have a look at 2019-2020 running totals for professional pool players CSP at: *http:/poolst.at/csp*. This highlights the best clutch shooters over all matches currently in our database. More data is being added constantly so the values will change. We do provide the total number of data points for measuring a player's CSP and most of the players data points are significant enough to take their CSP for 2019-2020 seriously.

We hope this sabermetric will be taken into consideration by pool leagues and organizations as a way to measure a player's clutch performance. Many things can be learned from stats about when a player is under pressure and many elements of the game can improve by studying CSP.

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