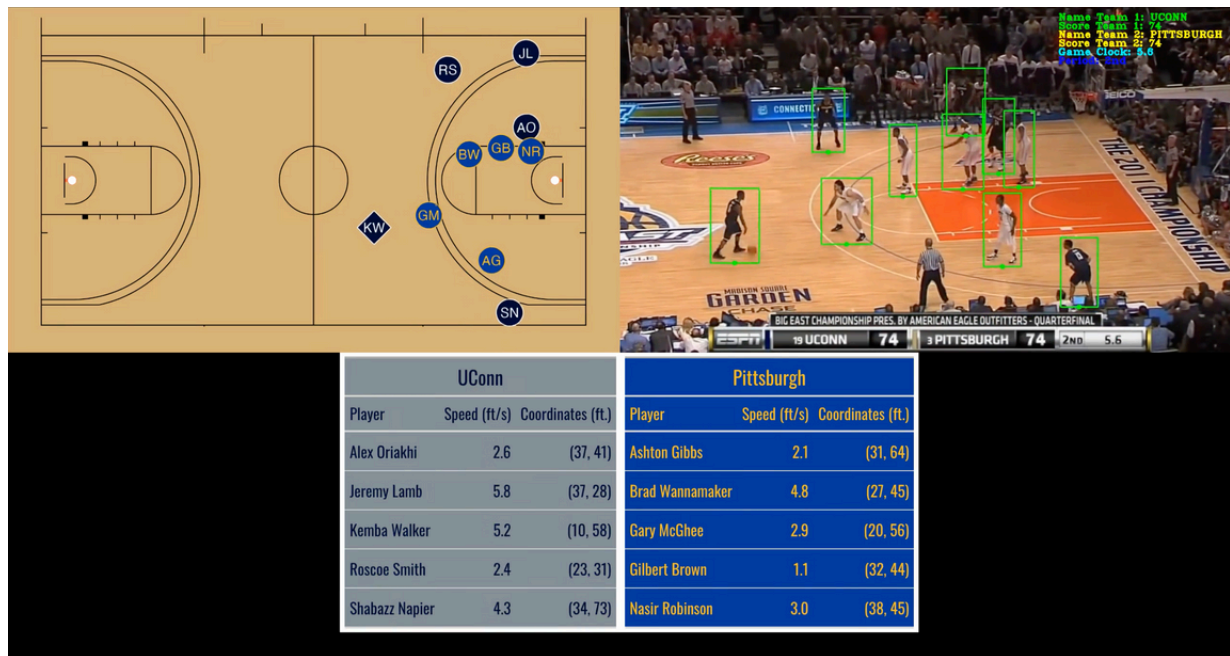


SHOT PROBABILITY MODELS EXPLAINED

Dive deep into how ShotQuality uses computer vision and AI to generate player location data which drives the most predictive shot models in basketball and the 5 factors which drive shot probability.

www.shotquality.com

Shot Probability Modeling Helps Drive Predictions



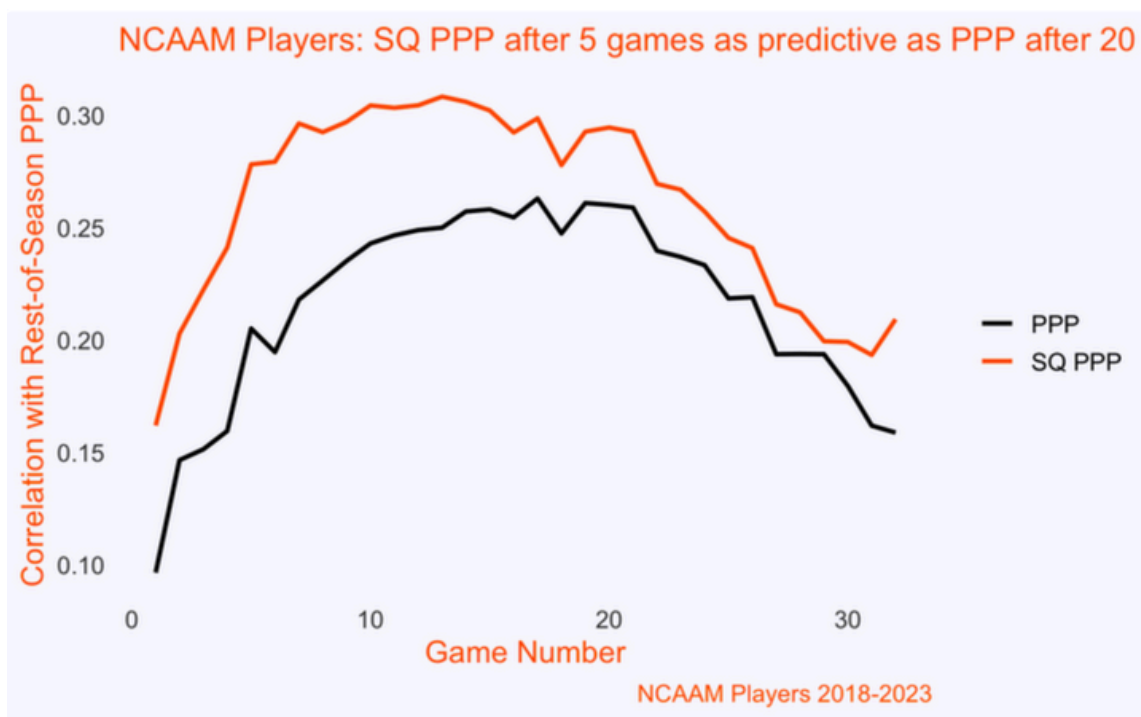
All basketball analysis tries to predict the future. We watch film and review box scores to guess what happens next. Unfortunately, past results can lie to us. Players and teams have hot and cold streaks. A great game or poor performance could be luck. It could also be a meaningful change in ability. Elite teams have off nights, poor shooters catch fire on a random Tuesday, and the basketball gods cause chaos every once in a while.

- **In 2022-23, Klay Thompson shot 33 percent from deep over the first month of the season.** A legitimate decline or just a cold streak? He returned to form and shot 43 percent over the rest of the season.
- **Over the first five seasons of his career, Andre Drummond only made 38 percent of his free throws.** In 2017-18, that number jumped up to 61 percent. Did he improve in the offseason, or just get luck for a few months? In the five seasons since then, he made 57 percent of his free throws. That 61 percent was not a fluke.
- **Marcus Morris shot just under 37 percent from three in his first nine seasons, then jumped up to 47 percent in 2020-21.** What happened? Did Morris unlock better shooting touch over the summer? It seems like the season was random, he shot just under 37 percent in the two seasons since.

“Unfortunately, past results can lie to us. Players and teams have hot and cold streaks. **A great game or poor performance could be luck.**”

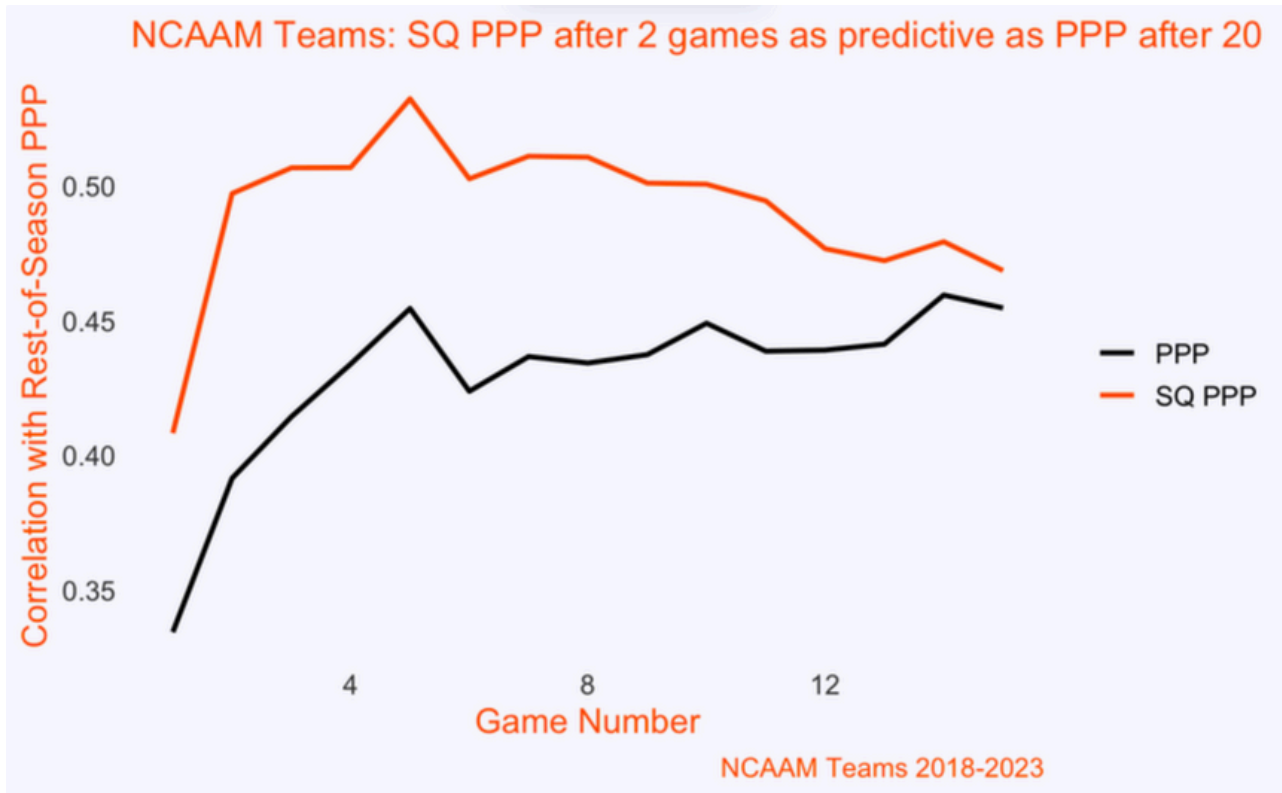
In the moment we do not know if our eyes and the box score lies to us or tells the truth. Here is where our shot probability model steps in to quantify regression. It analyzes the game at the building blocks of basketball: shots. If we work to predict the likelihood that every shot is made, we can imagine that a single game occurs thousands of times, or a player takes millions of the same shot. Increasing the prediction if teams or players beat it, and decreasing the it if they don't. We then learn how good players and teams actually are. And if we know exactly how good each player and team is, we can make better predictions about their futures.

How ShotQuality's Models Predict Player Performance



To summarize player's offensive efficiency, we simple ask, "how many points do you score per scoring opportunity?" Points per possession (true shooting attempt) cuts to the core of a player's offensive game. The black line on the chart below shows the traditional approach, showing the correlation coefficient between the player's season performance and their performance over the rest of the season. After one game, it is quite low, trying to predict the result of 30 games from such a small sample is difficult. At the halfway point of the season, traditional PPP's predictive ability improves, since it has a larger sample size, while predicting a large enough sample over the back half of the season to smooth out variance that could occur in one or two games. However, the ShotQuality PPP (SQ PPP) is consistently a better predictor throughout the entire season.

How ShotQuality's Models' Predicts Team Performance



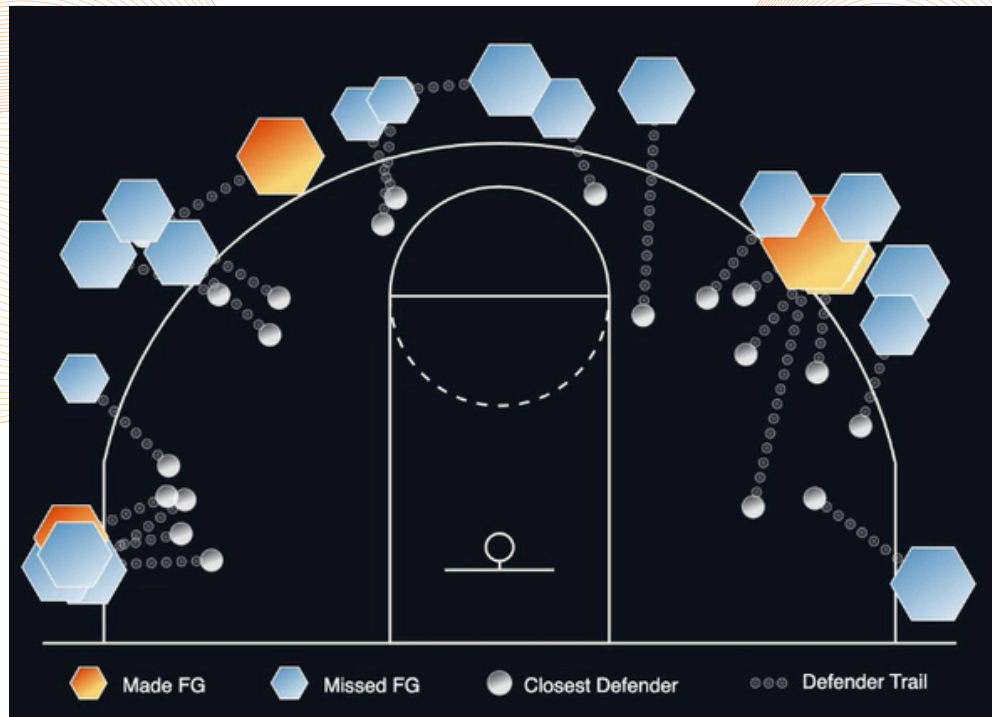
We observe a similar phenomenon at the team level. Looking at the first twenty games of the season, ShotQuality points per possession is more predictive of the rest of the season than the team's own performance.

How Do We Model Shot Probability? The Starting 5

The ShotQuality shot probability model has five main components and uses up to 100 variables in total between each of these sections:

- 1. Defensive Distance:** How does defensive ability and positioning impact the shot? I.e. the closest defender is eight feet away, there are three defenders within five feet of the defender, Houston plays elite defense, Delaware State plays poor defense.
- 2. Shooter Ability and Player Performance:** How good is the shooter? I.e. Stephen Curry is an elite three-point shooter, Josh Richardson is average, and Russell Westbrook is poor.
- 3. Play Type Descriptors:** What happened before the shot? I.e. transition, pick-and-roll, cut.
- 4. Shot Type Descriptors:** What happened during the shot? I.e. dunk, catch-and-shoot, off-the-dribble, shot distance.
- 5. Key Inferences:** How can we improve predictions while missing data? I.e. late shot clock shots tend to be rushed, players at Gonzaga tend to be good shooters, tall players tend to be poor free throw shooters.

The Value of ShotQuality's Shot Model



The goal of any basketball analysis is to learn from the past and make predictions about the future. At ShotQuality, our chosen weapon in this battle against space and time is our shot probability model. Our model not only out-predicts traditional statistics, it also makes these predictions earlier, making it better and smarter for both players and teams

#1: Defensive Distance - Location Data is Key

Defense is notoriously difficult to measure in all sports, especially basketball. A great rim protector deters drives to the basket. A lockdown perimeter defender is never challenged. At ShotQuality, we collect proprietary player location information to improve our model and analysis, along with modern approaches to classical team defensive analysis. Considerations for defense in the shot probability model fall into two groups:

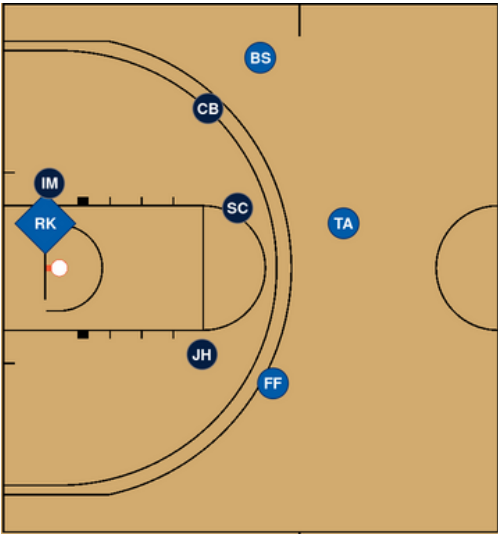
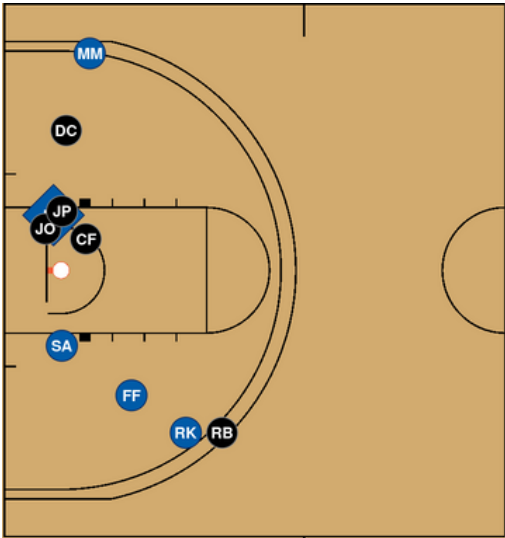
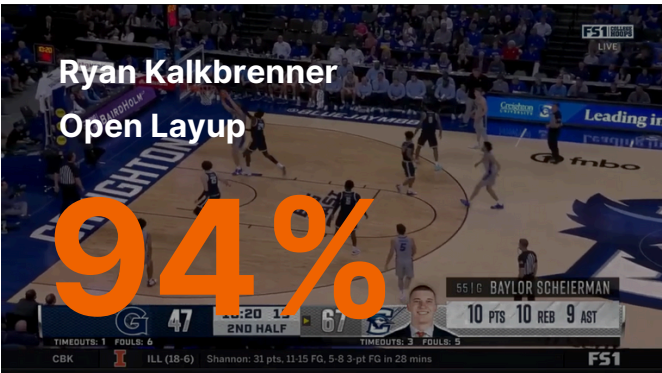
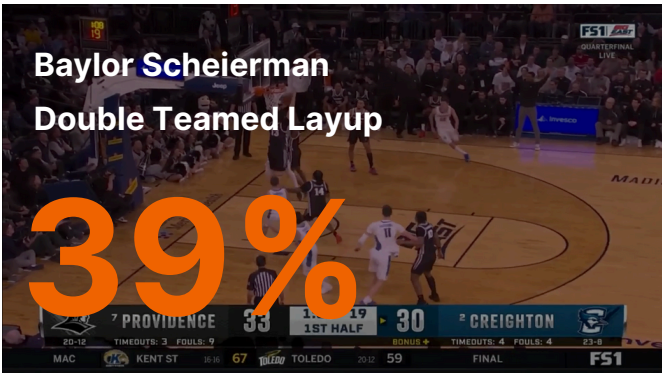
1. **ShotQuality location data:** where is the shooter and where are the defenders?
2. **Primary defender:** what characteristics do we know about the primary defender?

ShotQuality Location Data

A unique component of our shot model is the incorporation of our own proprietary data with the location and identity of every single player on the court at the moment of the shot that we create in-house using computer vision and AI.

Location Data Measures Defender Distance

The most obvious benefit of location data is the distance to the nearest defender or group of defenders. A tightly contested shot is more difficult than an open shot. A layup contested by a single player is easier to make than a shot contested by two or three players.



Location Data Measures Positioning

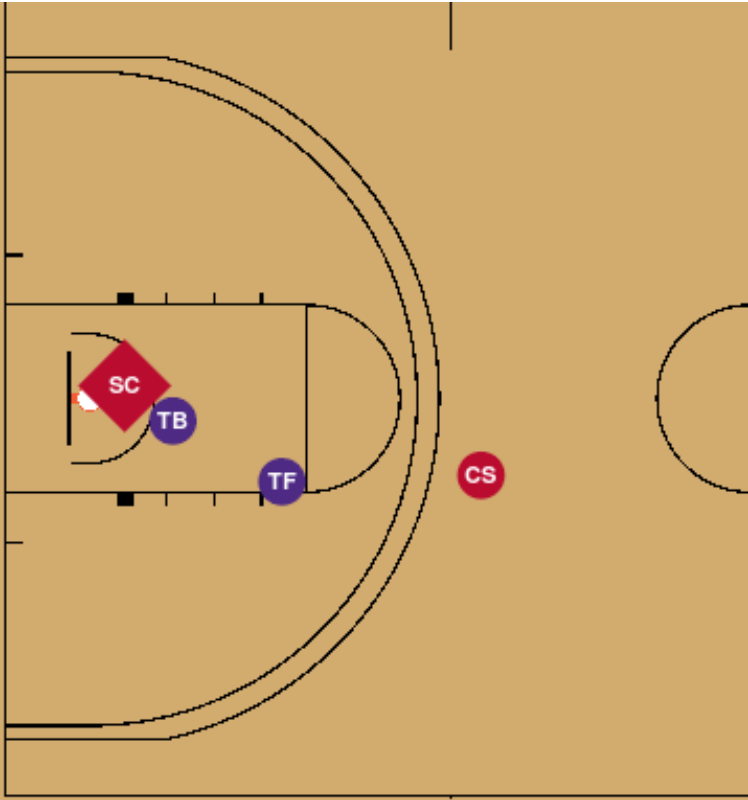
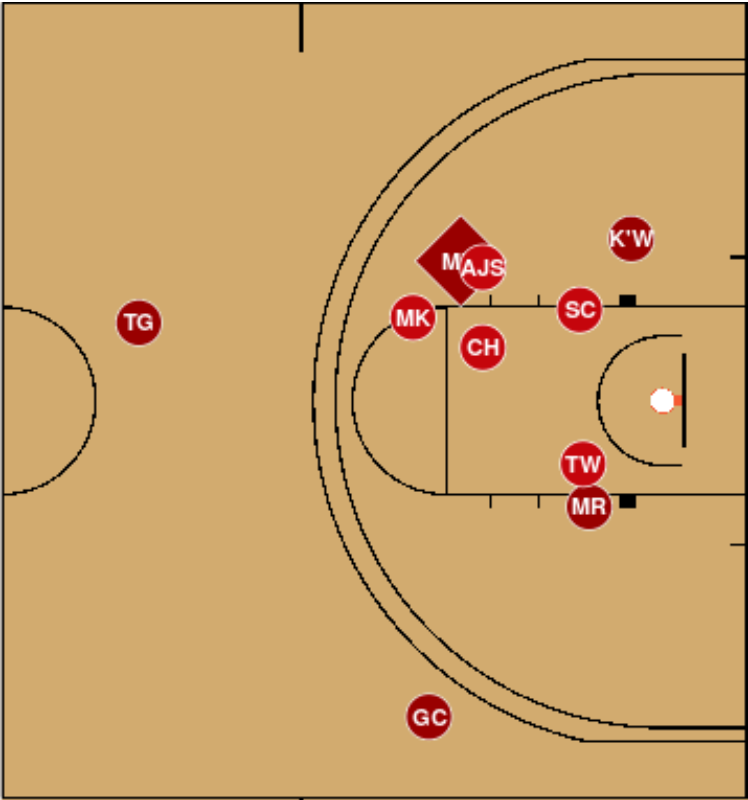
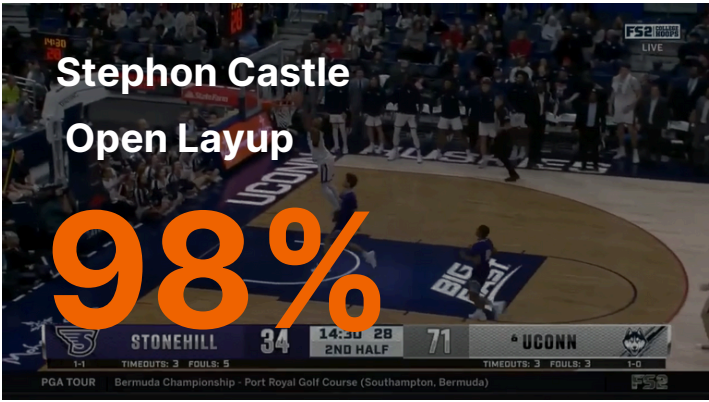
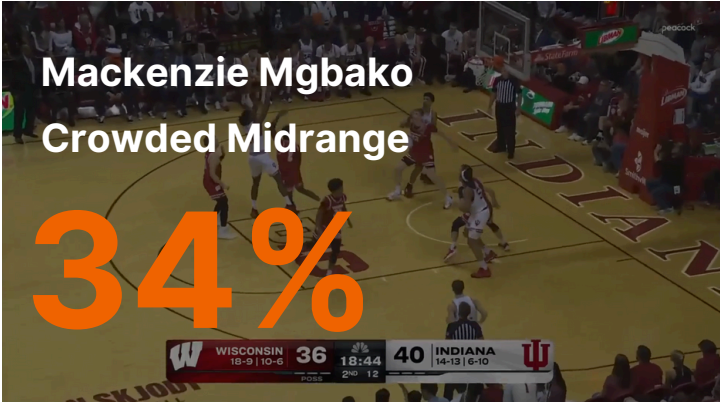
A defender between the shooter and the basket is most impactful. A driving layup with the defender behind the player is nearly an open layup, even if the defender is close. A defender on the side of a driving player is out of position, which yields some advantage to the offensive player.

Closest Defender Location	NCAAM Layup FG%	NCAAM Dunk FG%
Front	46%	79%
Side	53%	87%
Behind	63%	93%

Actual Field Goal Percentage by Defender Positioning 2022-24

Location Data Measures Crowding Effect

There is significant effect that the mere presence of defenders harms a player's ability to make a shot, even without a contest. In a crowded lane or midrange area, a shooter tends to rush or alter their shot in anticipation of defensive action. Even when no contest occurs, a shooter lowers their ability to make a shot by anticipating this defensive action.



Location Data Identifies the Primary Defender

The primary defender on a shot attempt alters a player’s ability to get into a good position for a rhythm shot in two ways: the defender’s height/length and the defender’s position. Tall defenders are more difficult to shoot over, especially impactful for inside shots. Tall defenders on the perimeter may deter a shot attempt from occurring, but they defend plenty of shots at the rim, and each additional inch makes it more difficult for offensive players to finish. Defender position also matters, if a slow and stiff center guards a three on the perimeter, they allow the shooter to more easily create space off the dribble or more time to release their shot. Similarly, a guard defending an inside layup may struggle, not only because of their height, but because of lack of experience defending that type of shot.

Closest Defender Height	NCAAM Layup FG%
< 6-0	68%
< 6-6	57%
< 7-0	51%
>= 7-0	48%

Field Goal Percentage by Closest Defender Height 2022-24 Season NCAAM

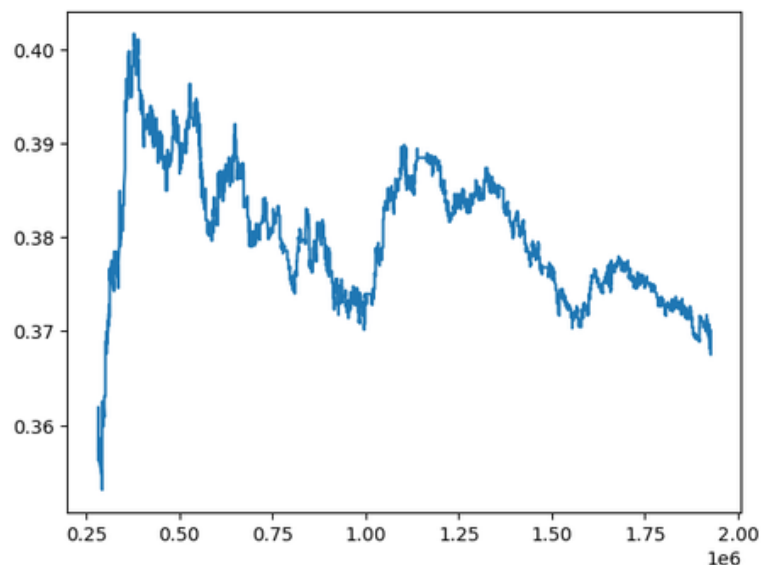
#2 Shooter Ability and Player Performance

We incorporate player ability by estimating their performance on an average shot for each shot type, this estimate blends three components: Player performance, Shot type and League performance.

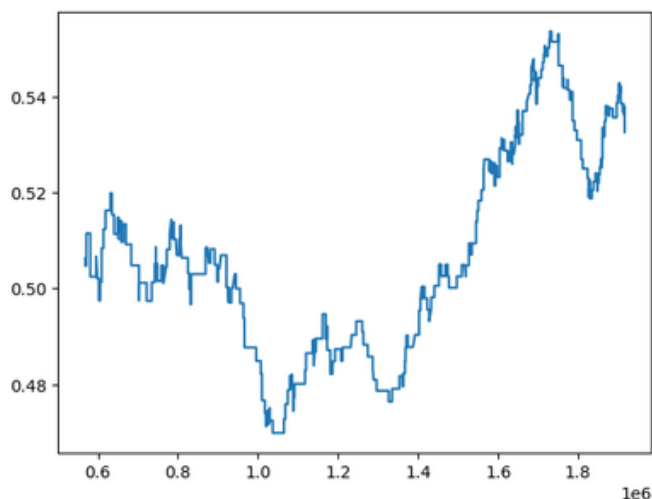
For a given shot type, we analyze a player’s entire career, with greater weight on recent performance. This means if a player improves or declines as a shooter, his or her ability estimate updates accordingly, but such changes demand proof. A single hot or cold streak cannot throw our predictions off. During a player’s freshman year in college, every shot changes their ability estimate since we knew so little about him. By the time the same player plays in his tenth NBA season, his rookie season shots have very little weight compared to the last few seasons.



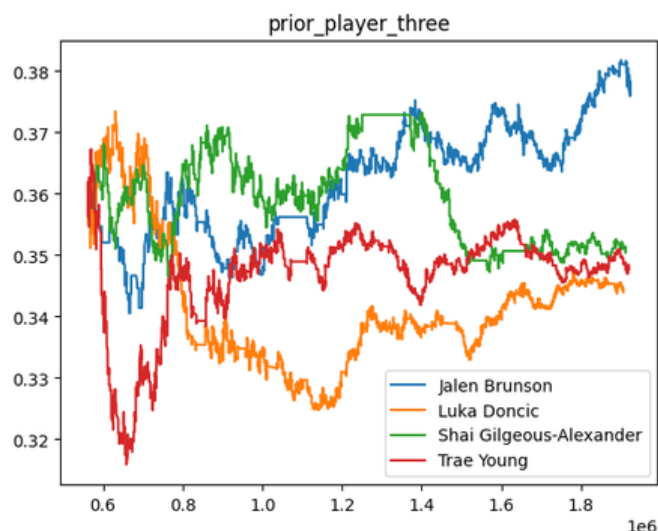
Jayson Tatum entered the league on fire, reflected by his true three-point ability estimate rocketing up to 40 percent during his rookie season. Since then, his three-point shooting steadily declined, making only 35 percent of his shots from beyond the arc these past two seasons. His ability estimate is still around 37 percent, since we believe he is better than the recent 35 percent performances, but we have seen enough evidence that he is not the 40-plus percent shooter we thought he was.



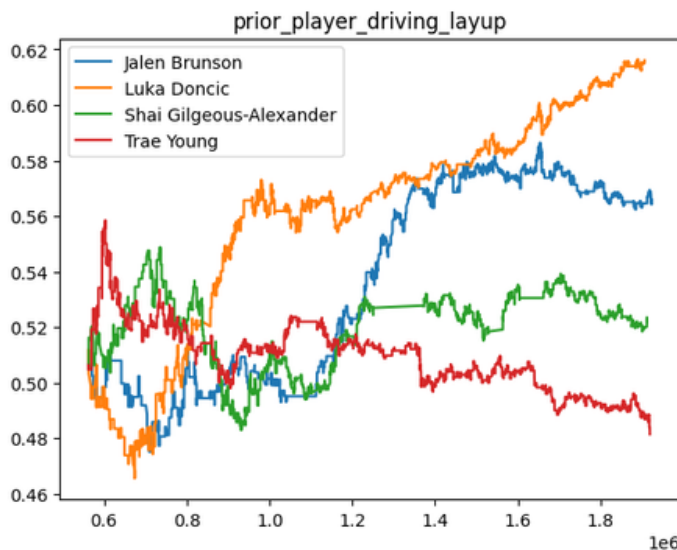
MIKAL BRIDGES DRIVING LAYUP



2018 NBA DRAFT CLASS THREES



2018 NBA DRAFT CLASS DRIVES



League Performance

Next we calculate the league’s performance level. In the 1990s, mens college basketball players made 67 percent of their free throws. Over time, players improved as shooters, making over 71 percent of free throws in the last six seasons. We observe the league’s level of performance as a starting point for all player estimates. Sometimes league performance reflects changes to the game, like moving the three-point line or illegal defense rules. This also reflects changes in the general ability of players for a specific shot type, jump-shooting skill increased in the past twenty years, but post-up skill declined.

Season	NBA Layup	NBA 3PT
2019	55%	35%
2020	54%	36%
2021	55%	37%
2022	56%	35%
2023	57%	36%

We then blend league-average performance with the player ability estimate. For players with many shots, their own performance makes up the majority of the shooter ability component of the model. For players with a small number of shots, however, padding with league ability is vital. A freshman attempting a jump shot may have insufficient three-point attempts to accurately measure ability. Other players may have very little playing time overall, such as NBA rookies and college freshman. With little to no performance history for those players, we optimize our predictions by assuming these players are league-average.

Shot Type

This blending varies by shot type. Three-point shots depend on heavily shooter skill, so we weigh league-average performance lightly. Tip-ins, on the other hand, are quite random, meaning we weigh league-average performance heavily, since we expect player performance to regress towards the league mean.



In addition to using a shot type’s shooter ability estimate, we use estimates for other shot types as well. Free throw ability indicates shooting touch, which improves jump shot predictions. Layups and dunks both depend on athleticism and finishing ability, so they both support each other’s predictions.



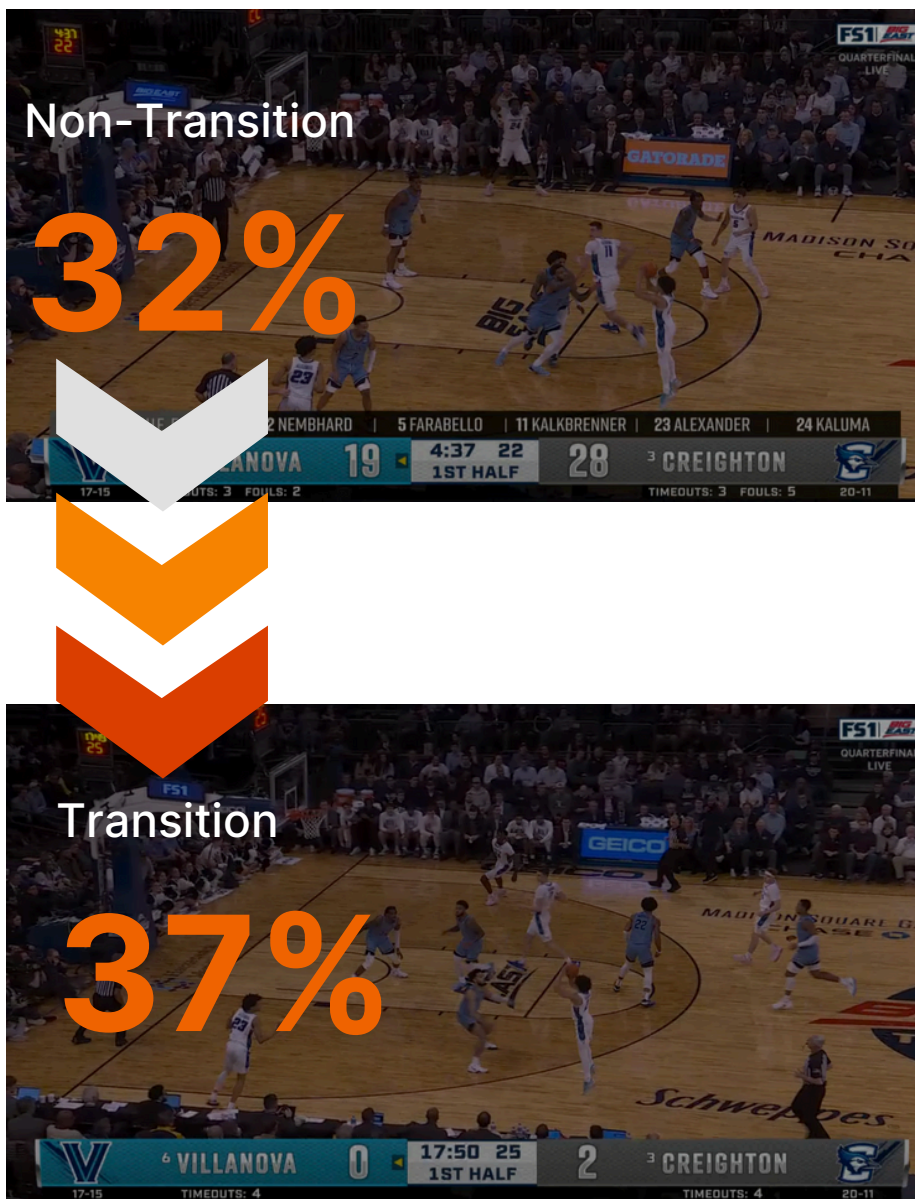
#3: Play Type Descriptors

A play type describes the events before the shooting motion begins. Here is a quick list of example play types: Pick-and-roll, Cut, Transition, Post-up, Off-ball screen, and Drive.

With each play types, we do not know if the shot was a jump shot or a layup, but we learn important context for the shot. Transition shots generally face lower defensive pressure, cutting players receive a pass if their teammate sees an easy opportunity for them, pick-and-rolls create mismatches. These inferences and others made from the data improve model predictions. We observe how performance changes among similar shots, but with different play types.

Shot Type	Play Type	NCAAM	NCAAW	NBA
<div>Layups</div> 	Driving	47%	43%	50%
	Non-Driving	57%	54%	59%
	Cuts	64%	63%	63%
	Non-Cuts	54%	53%	54%
<div>Jump shots</div> 	Transition	36%	34%	37%
	Non-Transition	34%	32%	36%
	Pick-and-Roll	36%	33%	39%
	Non-Pick-and-Roll	34%	31%	37%

Actual Field Goal Percentage by Play Type 2015-2023



In both plays, Nembhard shoots a moving three with similar defensive coverage. However, he receives a **+4.8 percent increase in the second shot because it occurs in transition**. The model learns that transition offenses face less organized defenses without defined matchups. In this play, the contesting defender scrambles late to disrupt an open shooter. In the first play, Villanova switches, but Justin Moore confidently closes out, knowing that his teammates are in defensive position. Nembhard then rushes his shot a bit to get it off before Moore shuts down the opportunity.

Knowing that a shot is taken in transition unlocks all of these details not explicitly captured. As always with models, this is a generality, and we take care to properly handle the true complexity of these actions.

#4: Shot Type Descriptors

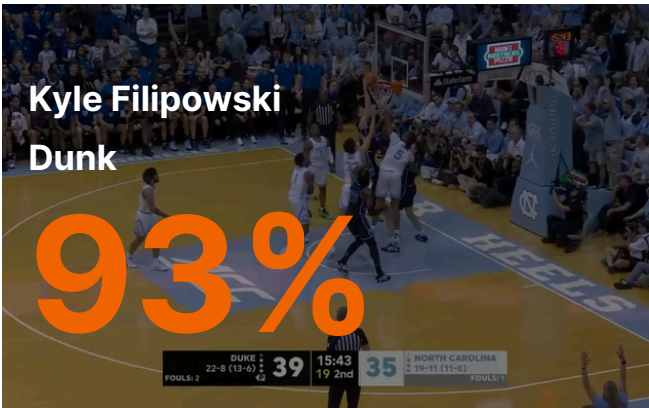
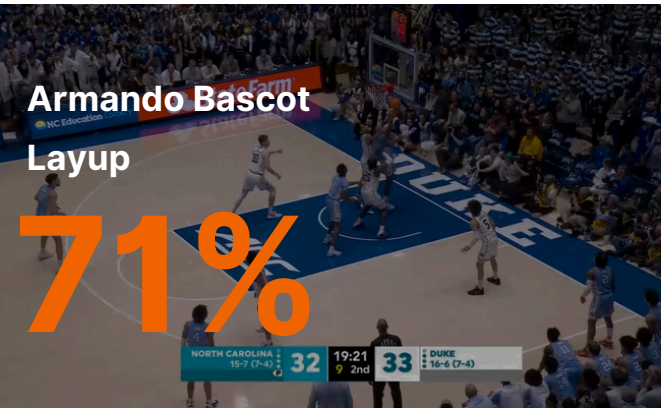
Shot types descriptors describes the shooting motion of a field goal attempt. A shot type is a broad basketball name for a shot, like jump shot, dunk, layup, or hook shot.

Shot Type	NCAAM	NCAAW	NBA
Jump Shot	34%	31%	38%
Dunk	87%	N/A	88%
Layup	56%	54%	57%

Actual Field Goal Percentage by Shot Type 2015-2023

A shot descriptor gives additional detail to the shot type, like wide open, catch-and-shoot, or right hand. Knowledge of the shot type sharpens model predictions. The average dunk is made more often than the average jump shot. The average field goal percentage of a shot type determines the starting point for all predictions. Shot type descriptors further decompose shot types, an off-the-dribble three is made less often than a catch-and-shoot three, and a contested layup is made less often than an open layup.

Shot Type Descriptor Film Review



In the first play, Armando Bacot misses a layup that we gave a 71 percent chance of going in, while Kyle Filipowski went up strong for a dunk that we predict he makes 93 percent of attempts. Both shots occur near the basket in a congested restricted area, but the taller Filipowski goes up with two hands and leaves no room for a defender between himself and the basket. Bacot, on the other hand, releases from one hand leaning away from the basket, giving him worse control over the ball and more room for defenders to alter his shot.

#5: Key Inferences

Sometimes we do not know a lot of information about a player, like college freshman, NBA rookies, and international players. Other times a player experiences a dramatic change, like transferring or improving over the offseason. In these instances, our shooter ability estimates can't tell the full story. For every elite shooting freshman that makes their first few threes of the season, another poor shooting freshman that started with luck and shot three-for-three. In the moment, we cannot know who is who. This is where some key inferences come into play.

Tall Players are Bad Shooters

The worst free throw shooters in NBA history are mostly centers. The best free throw shooters in NBA history are mostly guards. When a player has a short or non-existent history, their height and position provide valuable information. A seven-foot center is probably not a knockdown shooter, and a six-foot guard is probably an okay shooter. That same center is probably an okay layup maker, and the same guard probably struggles inside.

Free Throw Percentage

Height	NBA	NCAAM
Under 6 feet	81%	77%
6-0 to 6-6	80%	74%
6-7 to 6-11	74%	67%
Over 7 feet	71%	63%

Free Throw Percentage by Height 2015-2023



Layup Field Goal Percentage

Height	NBA	NCAAM
Under 6 feet	52%	51%
6-0 to 6-6	54%	53%
6-7 to 6-11	55%	57%
Over 7 feet	57%	58%

Layup Field Goal Percentage by Shooter Height 2015-2023

Good Teams Take Good Shots

Gonzaga, South Dakota, and Colgate have consistently been amongst the top three-point shooting teams in the country each year. This is despite constant roster turnover with recruits, transfers, graduates, and draftees. Teams achieve this with superior coaching, talent identification, and scheme. When a player joins an elite three-point shooting team, they are probably an above-average shooter, otherwise these teams would not continue their success with different rosters.

We extend this to other shot types. Purdue’s men tend to have good bigs, so a new center is probably above-average. Small schools tend to have smaller or less talented bigs, so their power forwards are probably below-average. Villanova tends to have skilled point guards, so freshman are probably above-average.

There are exceptions to these guidelines. We do not assume a new player on Gonzaga is instantly a 40 percent three-point shooter, but a player’s team and conference gives us valuable information about their ability.

Good Players Take Many Shots

Lastly, good players take more shots than bad players. Duh. This reflects their ability, good players should take more shots. Poor players taking many shots lose their attempts to the better players fairly quickly. That is the key here. Players with more shots are probably better scorers for a given shot type. Shooting volume reflects a player’s own confidence, and the information known by their teammates and coaches, who observe a much larger sample size in practice and shoot-arounds. Fans and analysts see very few shots compared to the hundreds or thousands of shots taken in private.



In Brook Lopez's first eight NBA seasons, he attempted 31 threes, making 3. In 2016-17, he took 35 in his first seven games, making 11! How? What happened? Lopez clearly spent long hours in the gym working on his jump shot, something unseen by the public, but well known by his teammates and coaches who saw his improvement every day. They gave him the green light from deep as he developed into a premier 3-and-D center.

From a small sample of 35 shots alone, we would assume a player is poor shooter, but the sudden spike in utilization beyond the arc signaled to us that Lopez is probably an improved shooter, and our predictions update accordingly.

Putting it All Together

ShotQuality's unique data for NCAAM, NCAAW, NBA, and WNBA games power the most predictive shot models in basketball. Put ShotQuality's models, regression analysis, and trends which are more predictive to work for your strategy.

Learn more about the ShotQuality by visiting ShotQuality.com.

