Is Football Fair? A Mathematical Look at Chance and Skill

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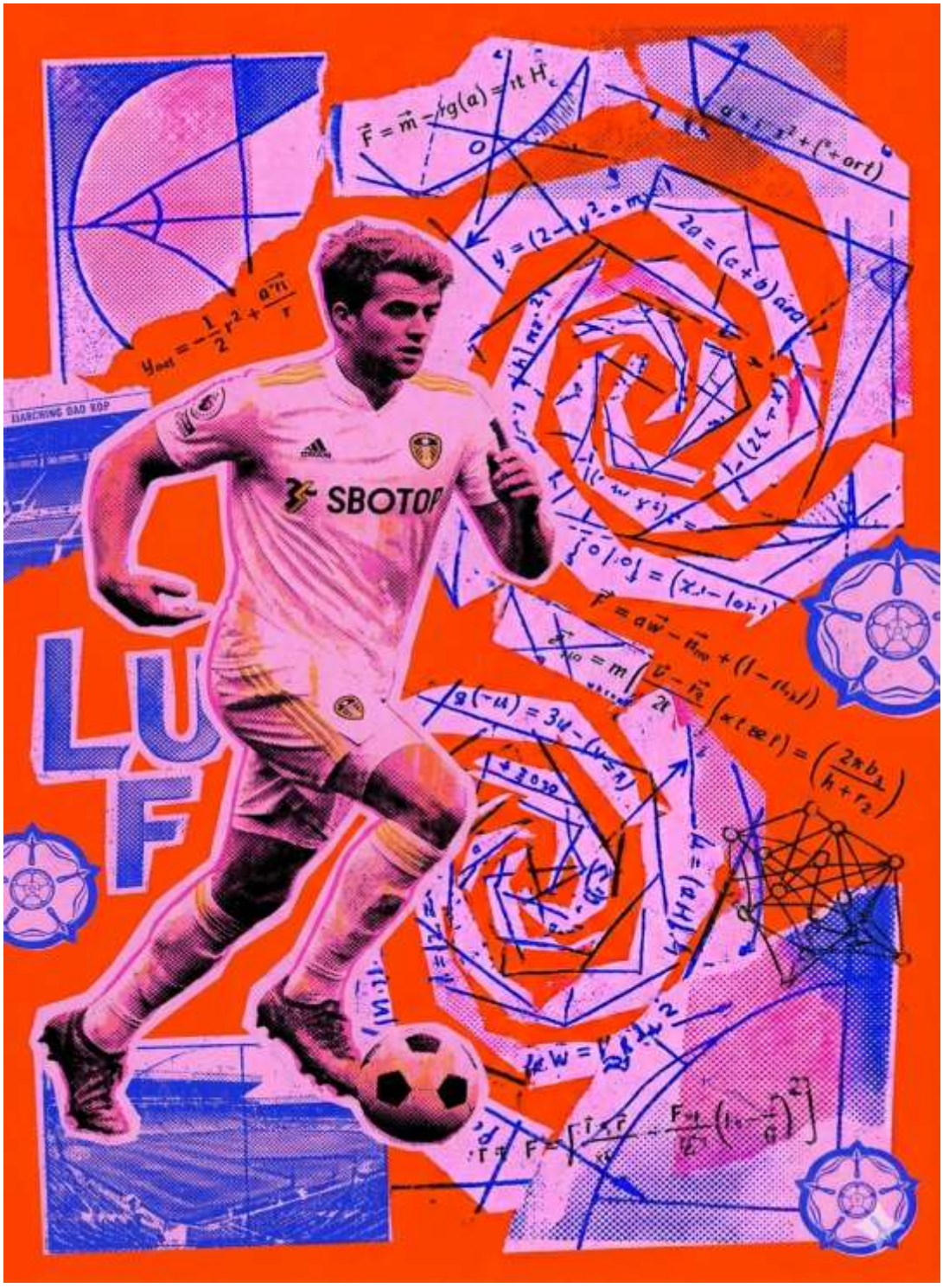

Problem Especification

A move, a shot, a pass can change everything, football is a sport of moments, in which full months of preparation, hours of practice and effort of 22 people can be reduced to a single penalty. Which, if we look at it objectively, sounds a bit unfair, but that's exactly what makes this sport so captivating and thrilling

Football is like that, its scoring system is low, which gives way to luck playing a decisive role. This has led to an attempt to minimize chance, analyzing in depth the plays, players and contexts and asking a natural mathematical question: is football a fair sport?

In this essay we will address this question by analyzing mathematically how probability, chance and different scenarios intervene in football, always arguing that apparent injustice is not a defect, but something carefully balanced that provides more spectacle.

What do we mean by "fair"?

In everyday life we say that a football match is unfair if our team does not win, however, we know that this is a very subjective stance, so for this essay we will define "fair" when the result is strongly correlated with the skill of a team. That is, a fair system consistently rewards the best teams with the best results. This does not mean that the top team must always win, as it would be unrealistic, but that skill should significantly influence the probability of victory.

It is important to distinguish between deterministic and probabilistic justice. On the one hand, deterministic justice is that equal inputs and outputs, in other words, means that the best team would always win. However, we know that football has never been like this, and here is where probabilistic justice comes in. It tells us that the team with the most skill has a better chance of

winning, but its victory is never assured. The question, then, is not whether chance exists, but how much influence it should have.

Imagine the two extreme scenarios, what if all the goals were a matter of chance? The skill of the players wouldn't matter, everything would be dictated by random scenarios, which would make football a completely unfair sport. Now let's look at the other extreme, if the best team always wins, this will make football predictable and lose all spectators' interest. Football exists somewhere at these two extremes, and that's what makes it wonderful. By adopting this probabilistic definition of justice, the problem becomes clearer: football is fair not if it eliminates chance, but if it balances randomness in a way that still allows skill to matter significantly over time.

This definition will serve as the basis for the analysis that follows. Rather than asking whether individual matches feel fair, the focus will be on whether the structure of football, as a system, will adequately mediate the relationship between chance and skill.

Goals are mathematically rare events

Unlike other sports, in football the results are decided by one or two goals, which makes goals mathematically unusual events, since for a goal to happen multiple variables must be considered, and this is where we will introduce the concept of expected goals (xG). This is a metric used to calculate the probability of a shot ending in goal, and although there are multiple models for calculating xG, for this test we will use the most common model based on the logistic regression formula. This expression is based on binary data, 0 and 1, so the result it returns to us is of the same form.

$$P(\text{Goal}) = \frac{1}{1+e^{-(\beta_0+\beta_1 x_1+\beta_2 x_2+\cdots+\beta_n x_n)}}$$

Equation1: Logistic regression equation

P(Goal): Chance that the shot will end in a goal.

e: Euler's number, approximately equal to 2.71828.

βi: Coefficients for each variable (based on actual cases)

x_i: Variables influencing the success of the shot.

These common variables influencing the firing may be as follows:

- Distance to the goal of the shot: At shorter distances, better odds.
- Angle with respect to the goal: The more centered the shot is, the greater the probability of scoring.
- Type of Shot: If it is with the foot, head or other body part.
- Defensive pressure: Number of opponents that must overcome the shot. At higher numbers of opponents, lower the odds.
- Type of attendance: Well-directed centers or passes increase the chances.

For this, we will show an example of what would be the calculation of xG in which a player makes a shot with his foot after receiving a pass between lines at 12 meters distance at an angle of 30° from the goal and with a defender ahead.

Assigning the values corresponding to the variables that influence the success of the shot:

- Distance (x_1) = 12
- Angle to the goal (x_2) = 30°
- Type of shot (x_3) = Foot (1 if with the foot, 0 if with another part)
- Defensive pressure (x_4) = 1 defender
- Pass type (x_5) = Between lines (1 if between lines, 0 otherwise)

The values of βi coefficients are based on analysis of multiple similar scenarios, in which they are assigned a value according to the importance of the variables influencing the shots. The result is that each variable receives a coefficient reflecting its actual average impact on goal probability. For example, if in historical data the shots closest to the archery end in goals more often, the distance coefficient will be negative or if the shots after a clean pass have more goals, the pass type coefficient will be positive.

Once this part is explained, the values of the coefficients would be:

- $\beta_0 = -1.2$
- $\beta_1 = -0.1$
- $\beta_2 = -0.05$
- $\beta_3 = 0.4$
- $\beta_4 = -0.3$
- $\beta_5 = 0.5$

Once the values are entered, we obtain that:

$$P(\text{Goal}) = \frac{1}{1+e^{-(-3.3)}} = \frac{1}{1+e^{3.3}} \approx \frac{1}{1+27.11} \approx 0.035$$

Equation2: Result of the proposed example

When mathematically analyzing the variables behind a goal, note that taking the previous example, we can say that the proposed goal opportunity looks at first glance like a clear scenario for scoring a goal, however, mathematically speaking the probability of goal is low, of only 3.5%, which evidence that the goal is an unusual or statistically rare event in mathematics and brings us to one of the central points of this essay, football is a sport of moments, where not always the team with more possession of ball or who creates more opportunities is the one that ends up winning, since a defensive error, a counterattack or a deflected shot can decide the balance for the opposing team. This is generally perceived as injustice; however, it can also be a matter of mathematical balance, in which football strikes a balance between skill and data with chance or drama. Recent analysis shows that no matter how much one tries to perfect the technique of shooting, passing, angle of aim or distance there will never be a 100% xG, nor will there be a 0% xG. It is within this range that football inhabits, this balance that allows us to perfect some factors, but always leaves room for uncertainty. This can be seen from the following illustration obtained from Opta Analyst, a company that collects data from different players worldwide.

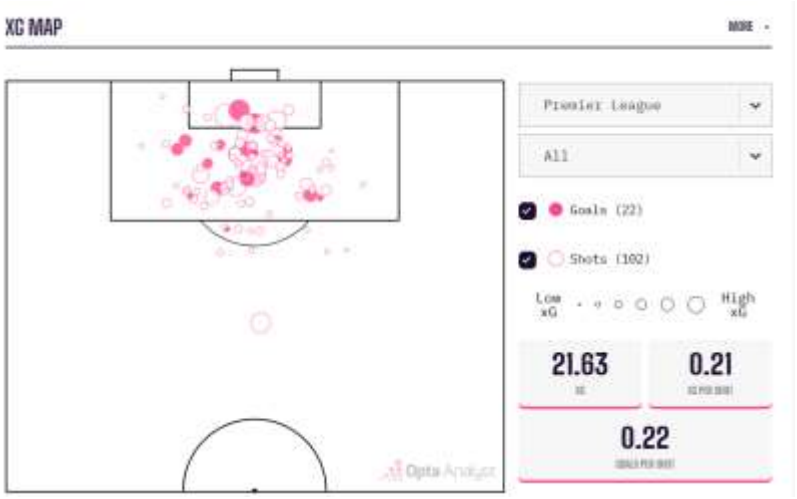

Illustration1: Erling Haaland's shot map

In this illustration, we see all the shots made by Manchester City's top striker, Erling Haaland, during the current Premier League season. Note that a world-class forward like the Norwegian needs 102 shots to score 22 goals, which is about 5 shots to score one goal, even at the highest level, efficiency remains limited, reinforcing the idea that scoring is difficult by design.

This analysis may lead us to think that football does not reward skill, however, it is totally the opposite, since it is evident that a team that generates more chances and plays better will have a greater chance of winning matches; in the end, the statistics always end up being balanced, that is, even if a match is lost, generating better chances of the rival in the long run, the results will be obtained if the statistics are maintained. In other words, the strongest teams tend to win more games, score more goals and concede less. Their superiority is visible in the sustained performance of the league, where the influence of chance gradually decreases. However, football is rarely experienced as a long sequence of repeated tests. There are tournaments where everything depends on individual matches, finals and knockout games, where the sample size is small and the variation is high. In these situations, randomness becomes much more visible. A

red card, a deviation, or a missed opportunity can outweigh the structural advantages built in months or even years. This means that football rewards skill, but in a statistical, not deterministic way, which means that better preparation brings us closer to success, but does not determine it. Seen this way, skill in football would be a probabilistic advantage, which explains why many teams can dominate over a season, but then in short tournaments the surprise is missed and they are eliminated because of one match.

Why Football Should Not Be Perfectly Fair

Football is a sport that achieves a wonderful balance between skill, discipline and preparation and chance, excitement and chance. Because a perfectly predictable system would quickly lose competitive tension. Consider the scenario in which football would be mathematically perfect, it would mean that the best always wins and become totally predictable, the same teams would dominate and the smallest would have no hope. But football resists this because of its design, as it does not disdain either scenario; allows players and teams to refine strategies and skills to get closer to success, but also leaves a margin for chance, an isolated move, a mistake, or an impossible shot that ends in a goal, which keeps the excitement and gives hope to smaller teams. In this sense, football illustrates a broader mathematical principle: systems that balance order and randomness often produce the most interesting behavior. Too much order leads to rigidity; too much randomness leads to chaos. Football occupies a narrow space between these extremes, where the results are uncertain but still intelligible.

Managing Uncertainty

By defining equality as the degree of balance between skill and chance, football's structure does not seek perfect justice; instead, it distributes the advantage probabilistically. Fundamentally, football's relationship to chance is no accident. Its low-scoring nature, continuous play and rare decisive events create a system in which uncertainty is inevitable. In this sense, football offers a compelling example of how mathematical systems work in sport and everyday life. It shows that fairness does not require certainty, and that unpredictability can coexist with structure. Football is not a game that eliminates chance, but one that carefully restricts it.

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