R22-13 Simulated effects of rough penalty on golfer distance and strategy

United States Golf Association, R&A Rules Ltd

November 2021

1 Summary

An average PGA TOUR golfer was simulated on a basic golf hole to determine if changes to rough penalty and course difficulty would create a change in optimal strategy off the tee. The maximum rough penalty tested represents a rough that causes a 40% increase in an average PGA TOUR golfer's proximity to the hole after the approach shot. No strategy changes were observed, even in the most penalizing conditions tested average driving distance remained constant.

Other factors simulated included fairway width, hole length, and green size. All factors showed changes to scoring, but none caused reductions in average driving distance.

2 Background

Many golfers today employ a strategy colloquially referred to as "bomb and gouge" (Rapaport, 2021). This strategy encourages the player to hit the ball as far as possible with little regard for the penalty of being in the rough. An area of investigation has been that to encourage players to take more care in striking the ball from the tee, there must be an increased penalty for being in the rough.

Prior work incentivized golfers to hit the ball a longer distance off the tee while at the same time providing increasing penalties for missing the fairway (USGA & R&A Rules Ltd., 2021). This work showed that players predominantly chose to use driver independent of the penalty for missing the fairway. Additionally, small increases in average accuracy and distance were observed where the penalty for missing the fairway was higher.

3 Introduction

The USGA-developed "Golfer Model" simulates a player's ability by defining their dispersion pattern for each lie they encounter on a golf hole. This dispersion pattern captures a player's likely left-to-right miss, as well as their short-to-long miss for a chosen target. Using this definition of a player's accuracy, their optimal strategy is determined based on the shot choices that will lead to the lowest possible score. By repeatedly simulating play of a hole using this optimal strategy, a player's average performance can be observed over performance metrics such as averages for number of strokes, proximity to the hole, driving distance, driving accuracy, greens in regulation (GIR), scrambling percentage, etc. After observing these metrics, changes can then be made to the player's ability (e.g., driving distance, accuracy from the rough, etc.) or course difficulty (rough difficulty, fairway width, etc.) to see their effects on player performance and strategy.

4 Golfer Model Overview

4.1 Model Summary

The playing of a golf hole is modelled as a Markov decision process. The golf hole is finely discretized into possible states from which the golfer may play a shot. Each of these states also serves as a possible aiming location (i.e., action) for the golfer. The golfer's left-right and short-long variability are drawn from a statistical distribution. These distributions are defined as a function of the lie and the intended shot distance, resulting in shot dispersion patterns that replicate what is seen in those conditions. With this information, given a starting and aiming location, the probability of landing at any ending location can be calculated.

The goal of the model, as in golf, is to minimize the number of strokes needed to complete the hole. This is achieved by valuing each state as that location's expected number of strokes to hole out. The expected number of strokes to hole out from any location is dependent on the next stroke and all future strokes following an optimal strategy.

The optimal strategy is one which always chooses the action with the minimum expected number of strokes. This accounts for not only the number of strokes from the expected landing location, but all the possible landing locations. The values of the possible landing locations are weighted by their probability of occurring. Since the transition probabilities are known, and the next state solely depends on the current state and action taken, the state values and optimal strategy can be solved by using dynamic programming methods.

Figure 2 illustrates the procedure for valuing multiple strategies for an individual shot. By performing this procedure for all possible aiming locations, the optimal aiming location can be found for that individual shot. This is performed for all locations a ball may come to rest. The result is a strategy for how to play each shot that might arise during the play of the hole.

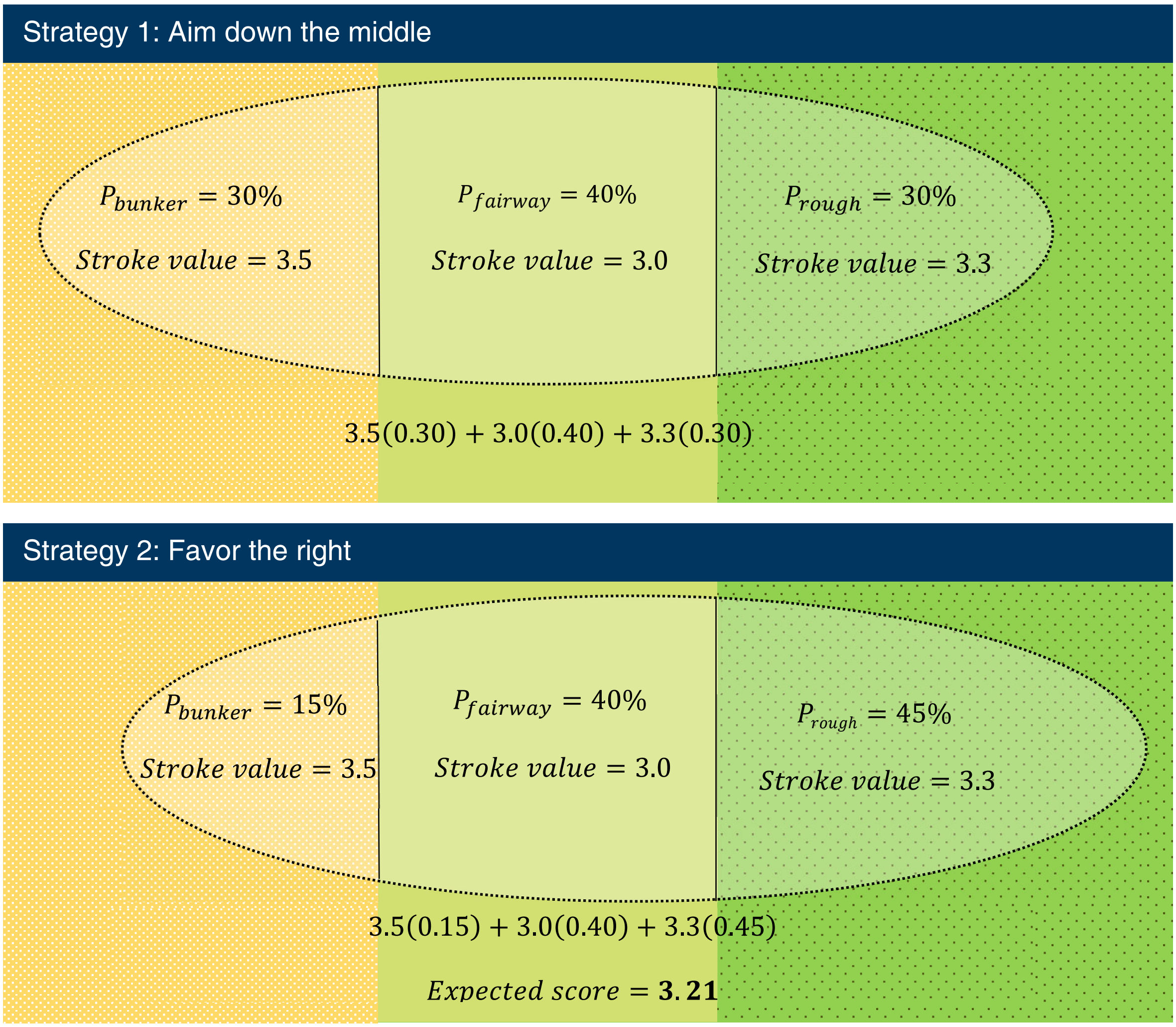

Figure 1: Expected score for two different aiming strategies. The ellipse represents a dispersion pattern where shots are likely to land given the golfer's accuracy. The stroke value is the number of strokes to hole out from a location when following an optimal strategy. Expected score is the weighted average of possible outcomes when following a given strategy. In this example, if Strategy 2 provides the lowest expected score over all possible strategies, the stroke value of the location the shot is taken from would be 4.21 (one stroke to hit the shot + the expected score). The numbers presented in this example are solely for illustration purposes.

4.2 Golfer Accuracy

The base accuracy defined in the Golfer Model was obtained by analyzing 2019 ShotLink data. The distribution of left-right and short-long variability for a variety of distances and lies were used to identify the general shape of the shot dispersion patterns under those conditions. The underlying distributions were then refined based on the PGA TOUR average proximity to hole metrics.

The putting model is based upon work that analyzed PGA TOUR putting performance (Fearing, Acimovic, & Graves, 2011). The model used here estimates the mean number of putts to be taken from a given distance for a field of PGA TOUR golfers. As the putting green simulated in this work only changes size, and not difficulty, this individual metric of putting performance is sufficient.

5 Method

To simulate increased rough penalty, the player's dispersion from the rough was defined as what would be expected from four varying levels of rough difficulty: average PGA TOUR intermediate rough, average PGA TOUR primary rough, 120% primary rough, and 140% primary rough difficulty[1]. Practically, these rough penalties may be achieved by altering the rough itself, or through changes to clubs used to hit out of the rough.

Figure 2: Test hole layout. Dimensions are not to scale.

Play was simulated on a basic "Test Hole" as shown in Figure 2. This test hole is a simplification of a golf hole to ignore the effects of penalty areas and other obstacles. The fairway width and teeing location of the test hole were varied to observe the effects. Green size was simulated at 20 x 20 yards (3,600 sq. ft.) and 30 x 30 yards (8,100 sq. ft.). These green sizes span the range of the smallest to largest average green sizes seen on the PGA TOUR (GCSAA).

Each of the combinations in Table 1 were simulated 25,000 times. This large number of trials allowed for the average results of the strategy to converge to their expected true value.

Table 1: Each combination of the following simulation variables was tested.

Rough Types	Intermediate Primary +20% +40%
Fairway Widths [yards]	15 30 50
Hole Lengths [yards]	400 450 500
Green Sizes [yards]	20 x 20 (3600 sq. ft.) 30 x 30 (8100 sq. ft.)

The golfer used for this simulation was defined to represent an average PGA TOUR player. This means the golfer's accuracy is defined such that their proximity to the hole from various lies and

[1] As defined by a 20% or 40% increase in variation in the proximity to the hole compared to average PGA Tour primary rough.

distances will match those of the PGA TOUR average proximity from those locations. The golfer's driving accuracy and distance are similarly defined. For reference, this golfer can drive the ball about 293 yds and hit the fairway 58% of the time on a 30-yard-wide fairway.

6 Results

6.1 Driving Distance

While there were noticeable changes in many golfer performance metrics (strokes, driving accuracy, scrambling, etc.), there was no change that affected the intended driving distance. In all cases, the intended driving distance was equal to the golfer's maximum potential. This shows that in all the scenarios tested, none were sufficient in creating a change in strategy off the tee. Table 2 through

Table **5** show the resulting average drive distances of playing the Test Hole under the specified condition using the optimal strategy. As a note, difference changes of 2.5 yards or less are a result of the 2.5-yard discretization of the fairway by the model, and not indicative of a change in optimal strategy. For example see notes on the, the apparent 2.4-yard change in Table 2.

Table 2: Average drive distance by hole length. *The apparent 2.4-yard increase does not indicate a behavior change. This is an artifact of the model's grid spacing.

Hole Length [yds]	Avg. Drive Distance [yds]
400	292.4*
450	290.4
500	290.4

Table 3: Average drive distance by fairway width. Distance increases are due to a larger number of balls landing in the fairway and thus having additional bounce & roll.

Fairway Width [yds]	Avg. Drive Distance [yds]
15	289.1
30	291.2
50	293.0

Table 4: Average drive distance by rough type shows no apparent change.

Rough Type	Avg. Drive Distance [yds]
Intermediate	291.1
Primary	291.1
+20%	291.1
+40%	291.1

Table 5: Average drive distance by green size shows no apparent change.

Green Size [sq. ft.]	Avg. Drive Distance [yds]
3600	291.1
8100	291.1

An increase in average drive distance of nearly 3 yards was observed with increasing fairway width from 15-yards to 50-yards, Table 3. However, this is not the result of a change in strategy with the optimal aiming location identified by the model remaining the same for all fairway widths. Rather, this change is caused by a greater proportion of fairways being hit from the tee on the wider fairway, resulting in more bounce and roll being observed.

6.2 Scoring

The most difficult combination of variables resulted in an average hole score of 4.84 (long hole, small fairway & green, difficult rough), while the easiest resulted in an average of 3.82 strokes.

Table 6: Effects of variable changes on the average hole score.

Variable	Change in average hole score
Hole Length	+0.04 strokes per 10 yd increase
Fairway Width	-0.07 strokes per 10 yd increase
Small Green	+0.10 strokes vs. Large Green
Rough Types	
Intermediate	-0.11 strokes
Primary	0.00 strokes (reference level)
+20%	+0.08 strokes
+40%	+0.12 strokes

Table 6 shows the change in average hole score as the model variables are changed. It is worth noting that these are the changes observed within the bounds described in Table 1. These results were generated using a hole without obstacles and a player representative of an average PGA TOUR player. These values would change if a more complex golf hole were simulated, or player models with different abilities were used.

7 Conclusion

These simulations show large changes to rough penalty did not lead to a change in strategy off the tee. Further penalizing rough above a 40% proximity to the hole penalty would need to be investigated to determine at what point strategy off the tee might be expected to change. Other penalties could be considered, such as the addition of penalty areas and out-of-bounds near the line of play to see if they influence strategy from the tee.

8 References

Fearing, D., Acimovic, J., & Graves, S. C. (2011). How to Catch a Tiger: Understanding Putting Performance on the PGA TOUR. *Journal of Quantitative Analysis in Sports, 7*(1). doi:10.2202/1559-0410.1268

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