Golf Course Effects on Hitting Distance

Findings from research conducted for Distance Insights primarily in 2020 and 2021.

March 2023

1 Introduction

On February 4, 2020, the USGA and R&A Rules Limited (herein referred to as The R&A) published a Statement of Conclusions (1), Summary report (2) and Library of specific reports (3) based on research conducted for the Distance Insights project. That research endeavored to be the most comprehensive review of the causes and impacts of increased hitting distance in the game of golf. As a result, the USGA and The R&A concluded that "we believe that golf will best thrive over the next decades and beyond if this continuing cycle of ever-increasing hitting distances and golf course lengths is brought to an end."

The following report summarizes research on a variety of golf course setup, conditioning, and design factors that could be used to influence hitting distance. It is important to note that these factors are not within the scope of governance by the USGA and The R&A, and their feasibility, cost, environmental impact, and potential effect on hitting distance vary significantly from hole to hole and course to course. These factors also have varying potential impacts on the experience and enjoyment of different types of golfers.

Our research throughout the Distance Insights project has shown that altering the design, setup, or maintenance of golf courses in an effort to manage increased hitting distance often has unintended or undesirable consequences in areas like resource consumption, maintenance costs, and the perceived integrity of a competition or golf experience. Our research also shows that these efforts are often ineffective or can even exacerbate distance issues. We believe that the contents of this report should be viewed through that lens.

2 Rationale and Considerations

Golfers intuitively understand that golf course factors like soil moisture affect how long a particular hole or course plays. We have all played golf after a significant amount of rain and observed that the course was playing longer than normal, but there has been little research into the measurable impact that golf course factors have on hitting distance and whether those "levers" could be reasonably used to influence play. We firmly believe that taking our understanding of the golf course effects in this document from anecdotal to objective has significant value, especially in the context of our ongoing Distance Insights research. We also recognize the risk of this data being misinterpreted or misapplied. For example, watering fairways in excess of turf needs can impact hitting distance, but it would also be environmentally irresponsible, detrimental to turf health, potentially expensive, and a departure from the norms of golf course preparation for a competition or daily play. Placing a large mound in the landing area of each hole would also serve to curb hitting distance, but at what cost financially and with what impact on the overall experience of playing a course or the integrity of the sport?

Translating the theoretical distance impact of these golf course factors into real-world outcomes is complex and fraught with challenges. Here are several important considerations about these factors that should be kept in mind as we evaluate their potential impact on hitting distance:

- **Applicability** – How relevant are these factors to various courses or holes within a course?
- **Practicality** – How feasible is it to manipulate these factors in a cost-effective and reasonable manner?
- **Sustainability** – What impact does utilizing these factors have on resource consumption and environmental responsibility?
- **Golfer Experience** – Will using these factors to influence play for certain groups or events have negative effects on the golf experience for other players?
- **Duration** – Can these factors be altered on a short-term basis or do changes require an extended period of time to implement? Can changes be easily reversed or are they inherently long-lasting?
- **Integrity** – Does using one or a combination of these factors to influence distance depart from the accepted norms of what is considered a reasonable challenge in golf?

Some of these factors are widely applicable, but not practical in most cases – e.g., regrading landing areas to stifle bounce and roll. Others are feasible at most courses but are environmentally irresponsible – like irrigating fairways in excess of turf needs for the sole purpose of decreasing distance. Understanding how complex the interactions are between golf course architecture, maintenance, resource use, and golfer experience gives us serious concern when we think about the factors in this report being used as tools to limit hitting distance.

This data should be viewed with the understanding that the potential impact any of these factors can have on hitting distance depends on a wide range of geographic and site conditions including soil type, grass species, and weather – which makes their application and impact inherently variable and inconsistent. Most of these factors also require an extended time horizon to alter, which inevitably means the average player will be affected even if they are not the target audience. Almost none of these golf course factors can be manipulated without some cost, which for the vast majority of golf facilities would be money better spent in other ways. Where golf course factors can be employed on a short time horizon, at minimal cost, and with no negative environmental impacts, there may be opportunities for reasonable application in managing hitting distance. However, after conducting this research our belief is that these situations are the exception rather than the norm.

3 Golf Course Distance Effects Research Overview

3.1 Categories of Golf Course Effects and Outline of this Report

The findings presented in this document are categorized based on the ease of implementation of each factor. Setup factors can be changed on a daily basis. Course condition factors can be adjusted with more effort and require longer periods of time to change. Finally, design factors can be most readily implemented during the initial construction of a course or during a renovation at generally higher cost. There is overlap among these categories depending on how each factor is being considered within a specific context. Table 1 provides an outline of the factor categories summarized in this report.

Report Section	Research Area
4.2	Setup-related distance factors
4.3	Conditioning-related distance factors
4.4	Design-related distance factors

Table 1: GOLF COURSE DISTANCE EFFECTS RESEARCH AREAS

This report examines twelve golf course factors which have been derived from previous research and identified by the USGA and The R&A as those most relevant to distance. This report conveys the results about the distance impacts of the factors listed below (placed into the category that fits best) regardless of level of impact:

- Course Setup Factors
  - Hole length (within the available tees)
  - Distance from tee to dogleg turn point (with available tees)
  - Penalty areas near the landing area (staked penalty areas)
- Course Condition Factors
  - Fairway firmness
  - Fairway mowing height
  - Grain direction
  - Fairway width
  - Rough penalty
- Course Design Factors
  - Landing zone pitch
  - Landing zone elevation
  - Penalty areas near the landing area (physical obstacles)
  - Hole length (adding new tees)

3.2 General Linear Model of Golf Course Effects on Distance

Eight of the twelve golf course hitting distance factors were studied during the statistical analysis project by Broadie (8) using six years of PGA TOUR Shotlink data from 2015 through 2020, supplemented with USGA shot tracking data. In this analysis, a General Linear Model identifies the relative contributions (Coefficient Estimates) of the different factors, showing the estimated distance impact in yards of the factors as studied. The General Linear Model parameter Coefficient Estimates, the Standard Error (a measure of the statistical accuracy of an estimate), and p-Value (the statistical significance) are shown in Table 2 for the variables studied.

Parameter	Coefficient Estimate	Std. Error	t-Statistic	p-Value
Intercept	274	0.319	859	<0.001
Course Elevation	0.00427	~0	73.2	<0.001
Fairway Width at 300 yds	0.432	0.00580	74.4	<0.001
Fairway Firmness Medium	-4.49	0.0759	-59.2	<0.001
Fairway Firmness Soft	-9.80	0.0906	-108	<0.001
Fairway Firmness Unknown	-4.09	0.173	-23.6	<0.001
Relative Player Driving Distance	0.963	0.00524	184	<0.001

Relative Player Accuracy	-12.4	0.651	-19.1	<0.001
Daily Temperature	0.150	0.00372	40.4	<0.001
Recovery Shot Frequency 3-6%	0.161	0.0841	1.91	0.056
Recovery Shot Frequency >6%	-1.94	0.150	-13.0	<0.001
Penalty Shot Frequency 1-2.5%	-2.49	0.0859	-29.0	<0.001
Penalty Shot Frequency >2.5%	-4.47	0.103	-43.5	<0.001
Rough Penalty (Delta Shots Gained)	-4.74	0.505	-9.39	<0.001
Wind	0.760	0.00482	158	<0.001
Elevation Difference Tee to Fairway	0.225	0.00190	118	<0.001
Short Hole (less than 450 yds)	-0.436	0.00155	-282	<0.001

*All variables are significant at the 1% level except Recovery Shot Frequency 3-6%

Table 2: AVERAGE DRIVING DISTANCE STATISTICAL ANALYSIS

3.3 An Important Consideration Prior to Application of the Results

The practicality, cost and impact on golfers can vary substantially across these factors and from course to course and even hole to hole. As a result, a full assessment of the possible range of implementation and maintenance costs for each course and/or event is beyond the scope of this document. Any changes to golf course setup, conditions or design should be planned with input from golf professionals, golf course superintendents, golf course construction professionals, golf course architects, or golf facility decision makers as appropriate.

3.4 Overall Summary of Golf Course Effects on Hitting Distance Factors

Figure 1 summarizes the golf course effects on hitting distance factors using a 2 x 2 matrix with the length of each bar indicating estimates of the range of potential cost and the color indicating the likely impact on experience of an average golfer. The vertical axis breaks the factors into the challenge of achieving a 10-yard distance impact for elite golfers while the horizontal axis separates the factors based on their feasibility and applicability. The 2021 Golf Course Builders Association of America Cost Guide Version 7 was used to estimate cost ranges (4).

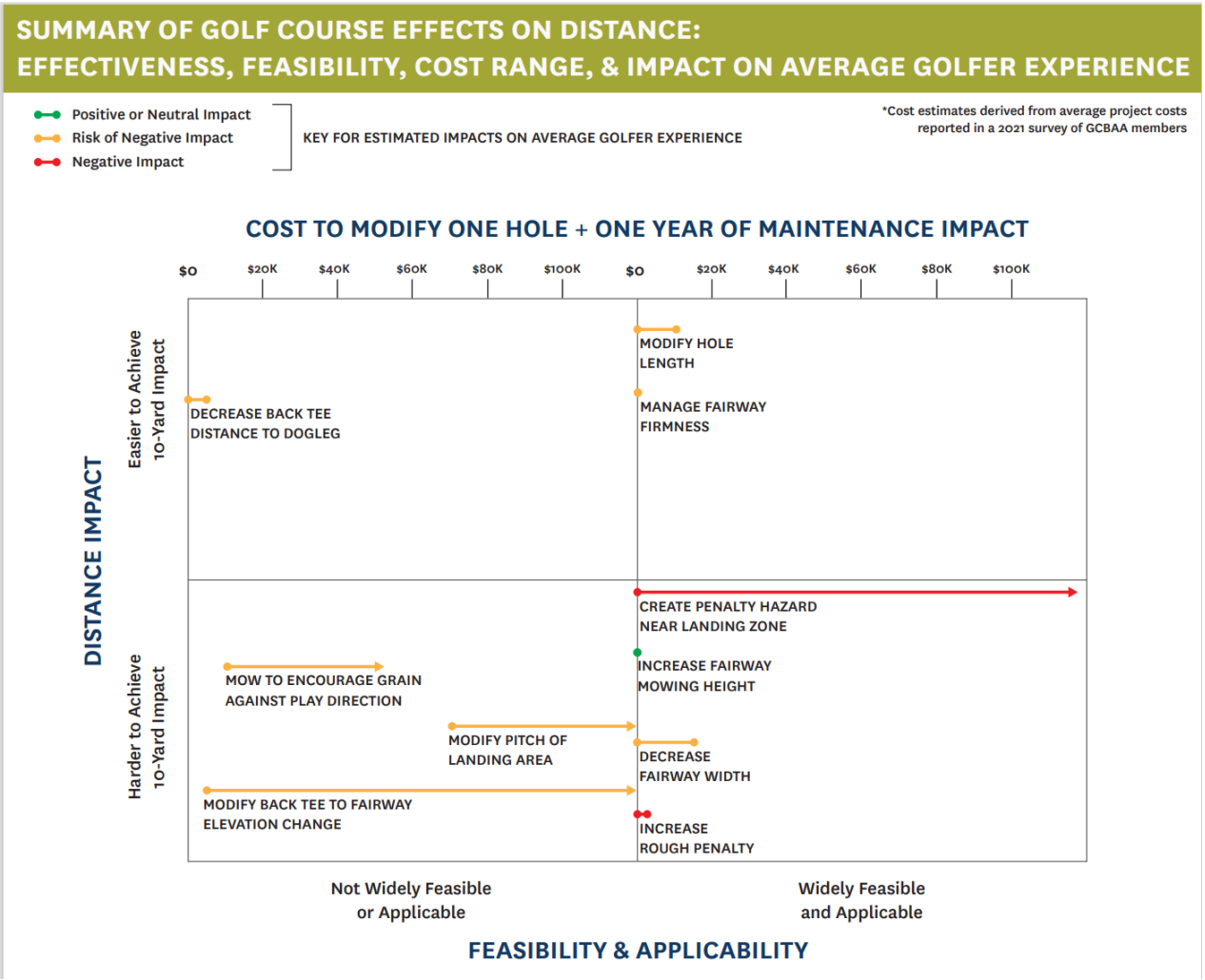

Figure 1: SUMMARY OF GOLF COURSE EFFECTS ON DISTANCE: EFFECTIVENESS, FEASIBILITY, COST RANGE, & ESTIMATED IMPACT ON AVERAGE GOLFER EXPERIENCE

3.5 Assumptions and Basis for Research

Where field testing or simulations were performed, variables were selected based on being representative of golfers of different skill levels or courses of varying agronomic conditions. Each detailed report in the Bibliography outlines the relevant assumptions and variables studied for the research performed.

4 Detailed Golf Course Distance Effects

Several golf course factors were investigated based on their having a reasonable likelihood to impact tee shot hitting distance either directly or indirectly. For example, fairway firmness directly changes the bounce-and-roll of tee shots. Other factors strongly influence tee shot club selection (5,6) (fairway width and hole length for example) and so the effect on hitting distance is indirect. An analysis of U.S. Women's Open data showed significantly less impact of course design factors on tee shot hitting distances for elite female golfers (7).

4.1 Data Sources

The current research drew on data from several sources to develop estimates of the potential distance impact offered by these golf course factors. Shot data from elite competitions – including PGA TOUR events and USGA championships – provided a significant portion of the data used in this study. The shot data from elite competitions were drawn from many players over the course of many events, which provides a statistically significant assessment of how golf course factors influence tee shot distance at the highest level of the game. We also used data from various field tests conducted as part of Distance Insights for recreational golfers. Our field studies provided additional context and allowed us to test specific adjustments, but the broad application of field test data is inevitably limited by the extreme variability found in the golf course environment. It is impossible to perform field studies that are extensive enough to account for all the different circumstances that influence these factors on golf courses.

4.2 Setup-related Distance Factors

4.2.1 Overall Context

This section focuses on setup factors. Setup factors can generally be changed on a day-to-day basis. These factors do not involve permanent changes to a golf course and their impact can be confined to specific events if desired.

4.2.2 Modifying Hole Length (within the available tees)

4.2.2.1 Distance Impact Per Hole

Hole lengths varied from 360 yards to 610 yards for these data. Included in the data set were a variety of par four and par five tee shot drive distances that were modeled using a General Linear Model to determine the influence of each factor.

Figure 2 plots the relationship between average drive distance and hole length. It shows that holes above 450 yards have no statistically significant effect on drive distance but that shorter than 450 yards, driving distance decreases. Above 450 yards, the impact of hole length modifications on driving distance is not statistically significant because players are primarily selecting driver and making full swings (5,6).

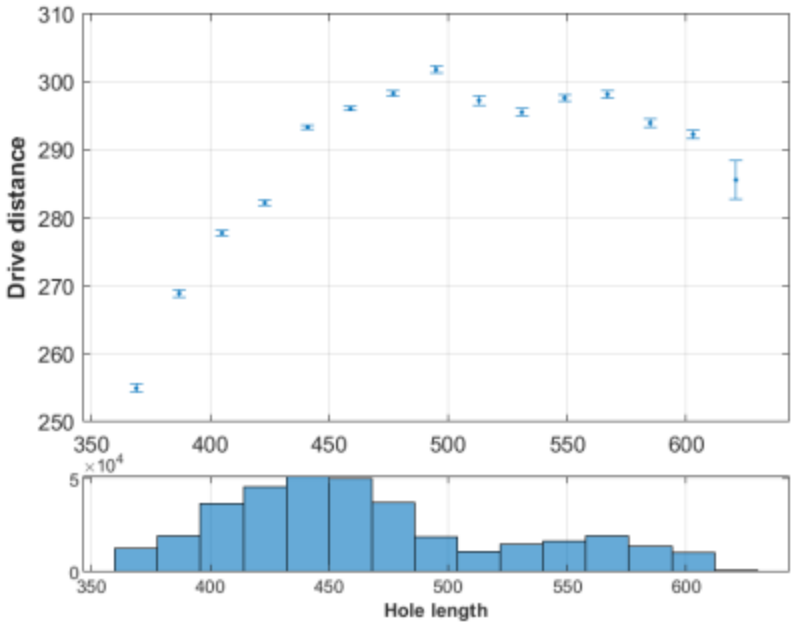

Figure 2: DRIVING DISTANCE AS A FUNCTION OF HOLE LENGTH. THE LOWER BAR CHART SHOWS THE FREQUENCY OF DRIVE DISTANCES WITHIN THAT HOLE LENGTH.

As shown in Table 2 for Short Holes (bottom row), those holes less than 450 yards, there is 0.44 yards of decreased tee shot distance for every yard that hole length is reduced below 450 yards in elite male competitions. Figure 3 shows that this is primarily due to reduced use of driver by elite male players (5).

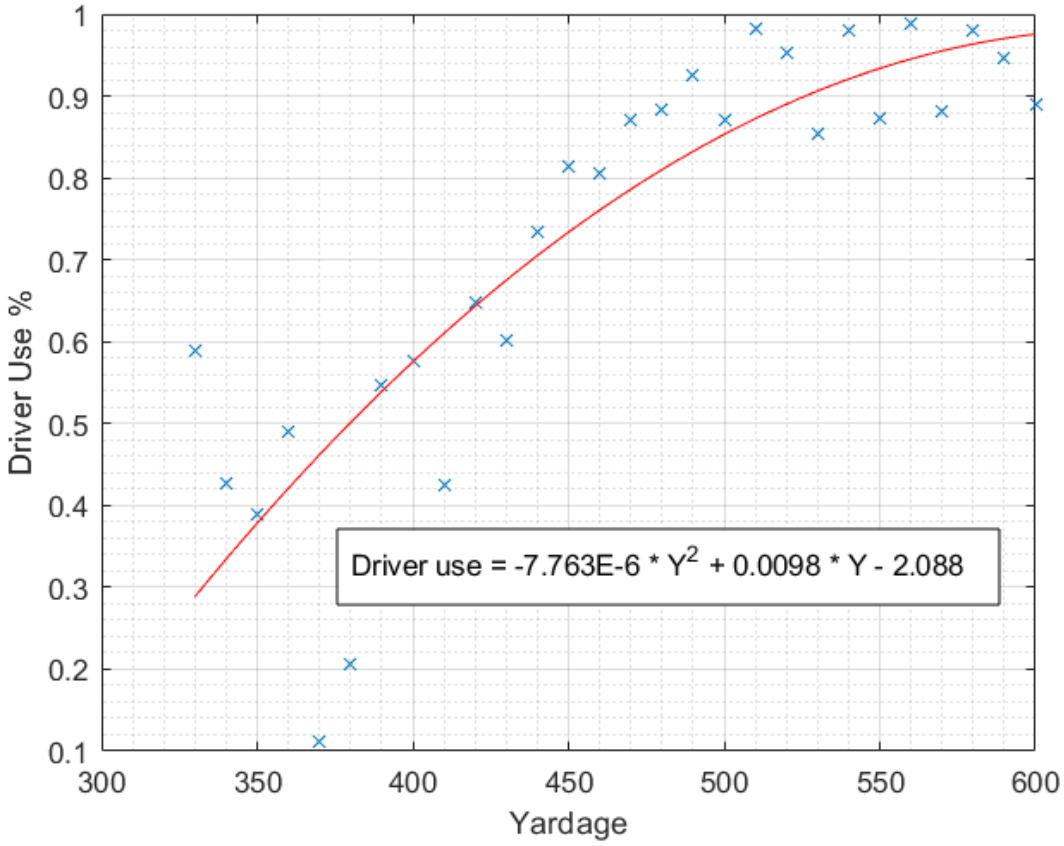

Figure 3: DRIVER USAGE BY HOLE YARDAGE ON THE PGA TOUR

4.2.2.2 Feasibility and Applicability

Decreasing hole length from the back tee can be achieved by playing from more forward tees. When viewed as a setup modification, shifting tees forward would only involve using existing teeing areas. Shifting back tees forward is feasible and applicable at most golf courses, especially for short-term purposes. Keep in mind that moving tee locations can have safety implications for players on that hole or on adjacent holes. It is important to note that decreasing average tee shot distance by reducing hole length does not make a course play longer; it only works because it discourages driver use and therefore changes the nature of the game.

4.2.3 Shortening Distance from Back Tee to Dogleg Turn Point

4.2.3.1 Distance Impact Per Hole

Distance from the tee to the dogleg turn point was another one of several golf course hitting distance factors that were studied during a statistical analysis project by Broadie (8) using the same data as described in Section 3.2. Doglegs can be used to effectively reduce tee shot distances. Analysis showed that where the physical layout and features of a hole created an effective dogleg with at least 35 degrees turn, reducing the distance to the turn point reduced tee shot hitting distances at a rate of 0.7 yards per yard of turn point distance reduction. This is different to changes in hole length because of the proximity of the dogleg.

Tee shot finishing locations are shown in Figure 4 for play during a competitive round on The TPC River Highlands 9th hole during the 2022 Travelers Championship. It clearly shows that tee shots on average finish past the turn point but are heavily influenced by sharp doglegs (see the high density of ball locations at the turn point).

Figure 4: Shotlink data from the 9th hole at TPC River Highlands during the 2022 Travelers Championship illustrates the impact that a sharp dogleg can have on driving distance in certain circumstances. The angle of this dogleg is 56 degrees and the average driving distance on this hole during the tournament was 271 yards, which is well below the PGA Tour average of 295-300 yards.

4.2.3.2 Feasibility and Applicability

Achieving distance impacts by shifting tees forward on a dogleg hole depends on the number of available sharp doglegs. Also, the distance impacts are dependent on the features and landscape inside the corner of the dogleg. On a tree-lined hole, the distance decrease can be significant if players can't clear the trees – in a grassland setting players may simply cut the

corner if the back tee is shifted forward. The average dogleg angle in the study was 20 degrees, so 35 degrees or greater represents a sharper-than-average amount of turn.

Although not specifically studied and quantified, the distance to the dogleg turn point for recreational golfers that would change their behavior will be relative to their hitting distance and different than elite male golfers.

Creating new dogleg holes is not a course setup change but a more costly and disruptive design change that is not discussed in this report and which could have player safety implications.

4.2.4 Penalty Areas Near the Landing Zone (staked penalty areas)

4.2.4.1 Distance Impact Per Hole

Driving distance changes from placing a penalty area near the landing zone was another of several golf course hitting distance factors that were studied by Broadie (8) as described in Section 3.2.

As shown in Table 3, an abbreviated version of Table 2, the study found 4.5 yards of decreased tee shot distance when a penalty area is located near the landing zone in a way that creates a relatively high risk (i.e., >2.5% of tee shots) of incurring a penalty. When the likelihood of incurring a penalty is reduced, the effect on average driving distance decreases and eventually has no effect on average driving distance.

Parameter	**Coefficient Estimate**	**Std. Error**	**t-Statistic**	**p-Value**
Penalty Shot Frequency >2.5%	-4.47	0.103	-43.5	<0.001

*All variables are significant at the 1% level

Table 3: AVERAGE DRIVING DISTANCE STATISTICAL ANALYSIS FOR HIGH FREQUENCY PENALTY SHOTS

4.2.4.2 Feasibility and Applicability

When appropriate, marking penalty areas near the landing area using red, yellow or white stakes is a common practice.

4.3 Conditioning-related Distance Factors

4.3.1 Overall Context

This section focuses on course condition factors. Course condition factors typically require more effort to adjust than setup factors and require longer periods of time to change. These factors can be adjusted on a temporary or permanent basis and their effectiveness and resource impacts will vary considerably based on existing site conditions.

4.3.2 Fairway Firmness

4.3.2.1 Distance Impact Per Hole

Driving distance change due to changes in fairway firmness was another of several golf course hitting distance factors that were studied during a statistical analysis project by Broadie (8) using the same data as described in Section 3.2. The statistical model coefficients and statistical significance are shown in Table 4 with the relevant parameters. Compared with firm fairways, medium firmness fairways reduced tee shot distance by 4.5 yards and soft fairways by 9.8 yards.

Parameter	**Coefficient Estimate**	**Std. Error**	**t-Statistic**	**p-Value**
Fairway Firmness Medium	-4.49	0.0759	-59.2	<0.001
Fairway Firmness Soft	-9.80	0.0906	-108	<0.001
Fairway Firmness Unknown[1]	-4.09	0.173	-23.6	<0.001

*All variables are significant at the 1% level

Table 4: AVERAGE DRIVING DISTANCE STATISTICAL ANALYSIS FOR FAIRWAY FIRMENSS

Separately in June 2018, the USGA initiated field testing to determine how bounce-and-roll distance was impacted by grass species, mowing height, mowing direction, soil moisture and organic matter content (9). A total of 624 bounce-and-roll distance measurements were recorded using a portable golf ball launcher calibrated to simulate inbound drives from various launch angles. Moisture levels of the soils at each test event ranged from 29 to 42 percent, with most readings at a moisture level of 36 percent. Note that the typical PGA TOUR drive has an inbound angle of 38-39 degrees and lower angles are expected for shorter hitting recreational golfers.

These studies found 2-15 yards of distance reduction was observed when compared to baseline conditions by increasing fairway moisture content 5-8% with a reasonable irrigation cycle of 0.15-0.20 inch. The average reduction was between 5-10 yards. Note that as shown in Figure 5, the results are non-linear and there are interactions between angle of impact and moisture content.

[1] Fairway firmness listed as “Unknown” in Shotlink data. Based on the Coefficient Estimate, this may not be practically distinguishable from “Medium”, implying that it is similar to Medium on average.

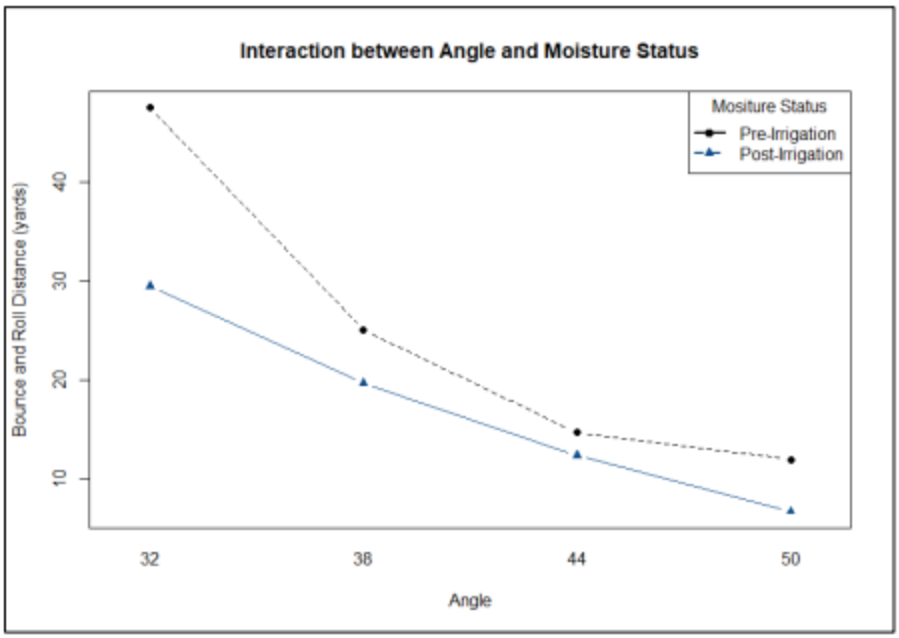

Figure 5: INTERACTION BETWEEN ANGLE AND MOISTURE LEVEL

4.3.2.2 Feasibility and Applicability

Maintaining fairway moisture levels to reduce bounce-and-roll for short periods of time that are suitable for healthy turf is feasible for golf courses with fairway irrigation coverage and an adequate water supply. It is not recommended to increase fairway moisture levels beyond water requirements for healthy turf. However, facilities should be aware that drying down their fairways will lead to increased hitting distance and may cause turf stress. For courses in areas where water is expensive or where water use is restricted, or where there are environmental concerns, challenges may be faced with managing fairway moisture levels for the purpose of reducing bounce-and-roll distances.

In many parts of the world, water availability and cost are critical factors in sustainability of golf courses. The industry has been committed to actively reduce water consumption for maintaining golf course turf (12). Using irrigation to soften fairways runs counter to these needs and trends.

4.3.3 Mowing Height

4.3.3.1 Distance Impact Per Hole

The June 2018 USGA bounce-and-roll project investigated the distance impact of mowing height (9). This study found that over a tested range of 0.35-0.60 inches height of cut (HOC), the difference in bounce-and-roll was 2-4 yards, equating to 1-2 yards per 0.1-inch change. No difference was observed below 0.40 inch. Testing was not conducted above a 0.6-inch HOC because of lack of availability. The maximum achievable tee shot distance impact is likely in the range of 2-4 yards per hole given the typical mowing heights for the most commonly used fairway grasses.

4.3.3.2 Feasibility and Applicability

Raising fairway HOC can be done reasonably and at minimal cost on most golf courses. The amount of increase possible depends on current mowing height, grass type and golfer expectations. For temporary changes, it is not recommended to increase fairway height more than 30% because of potential scalping and turf issues when returning to the original HOC. Grasses like bentgrass and bermudagrass may not play well at heights above 0.5-0.6 inch, while other grasses may perform acceptably at 0.75 inch.

4.3.4 Grain Direction

4.3.4.1 Distance Impact Per Hole

As another part of the June 2018 USGA bounce-and-roll project, the distance impact of mowing direction to form grain was investigated (9). Distance impact of grain direction was highly dependent on grass type: of three types tested, bentgrass and *Poa annua* fairways showed 0-3 yards difference based on direction of cut. A high-cut Zoysiagrass fairway for which the grain was intensified by mowing in the same direction over multiple months had a statistically significant difference of 11 yards of distance between shots landing with the grain versus into the grain, although it should be noted that this specific difference represents the extremes of grain direction mowing and in specific circumstances.

4.3.4.2 Feasibility and Applicability

The ability to encourage fairway grain into the direction of play varies by grass type. Some grasses will not typically produce impactful grain even with repeated mowing in one direction. Encouraging grain in the direction of play also requires mowing fairways toward the tee over an extended period of time. This has undesirable equipment and labor cost increases. Attempting to encourage grain also diminishes mowing quality, which may lead to scalping, thin turf and disease impacts. It is not recommended to promote grain because of the negative impacts on turf health and the cost.

4.3.5 Fairway Width

4.3.5.1 Distance Impact Per Hole

Fairway width and rough penalty (next Section 4.3.6) are complex variables that interact with each other and with hole length. As described in Section 4.2.2 for holes longer than 450 yards, elite male golfers generally hit driver to maximize tee shot distance in an attempt to minimize their expected score. As shown in Figure 6, driving distance is not affected by fairway width for long holes (orange curve), except possibly at the widest of fairways (above 65 yards).

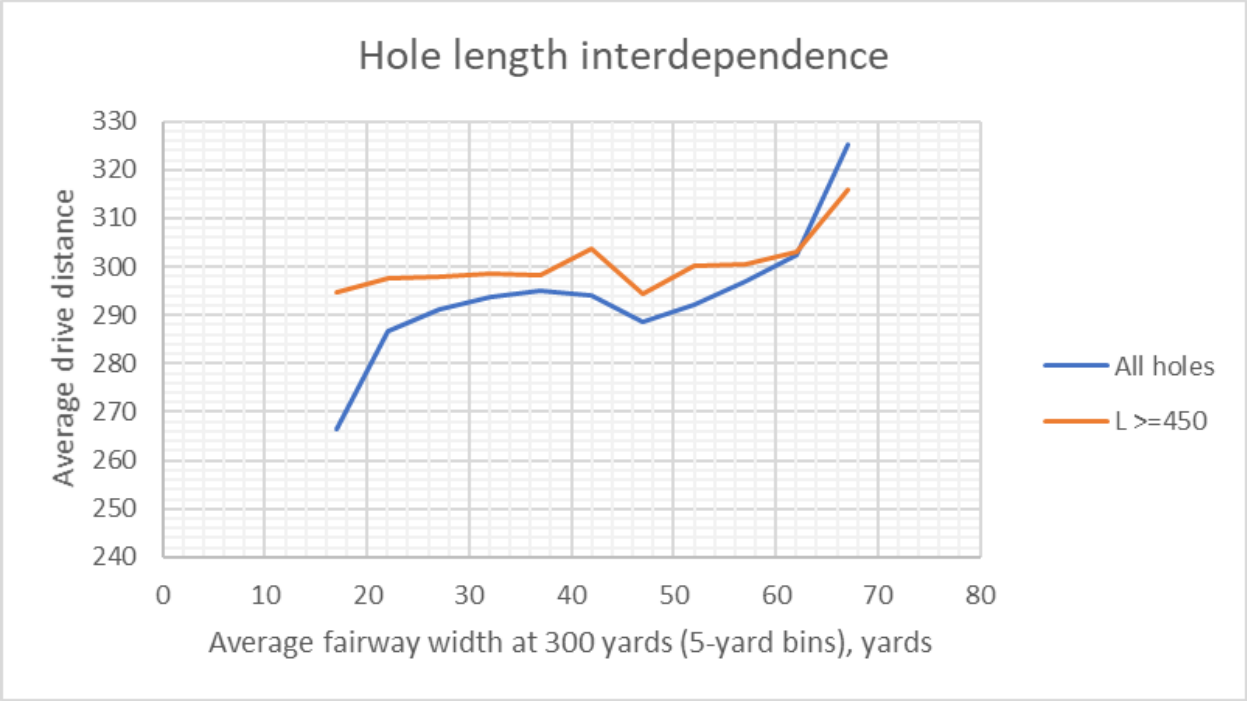

Figure 6: 2020-21 DATA: SEGREGATE LONG HOLES FOR AVERAGE DRIVING DISTANCE VERSUS FAIRWAY WIDTH

For shorter holes, a non-linear relationship between fairway width and hitting distance is hypothesized: as holes get very wide or very narrow, there may be a lower premium on accuracy.

Driving distance change due to changes in fairway width was another of several golf course hitting distance factors that were studied during a statistical analysis project by Broadie (8) using the same data as described in Section 3.2. It is also significant that fairways narrower than 20 yards occur on average on shorter holes (less than 425 yards) which represent only about 6-7% of holes studied (10). Overall, this study found that 0.43 yards of distance decrease was observed per yard of decreased fairway width for players in elite male competitions as shown in Table 5.

Parameter	**Coefficient Estimate**	**Std. Error**	**t-Statistic**	**p-Value**
Fairway Width at 300 yds	0.432	0.00580	74.4	<0.001

*All variables are significant at the 1% level

Table 5: AVERAGE DRIVING DISTANCE STATISTICAL ANALYSIS FOR FAIRWAY WIDTH

It should also be noted that frequently fairways narrow in the landing zone due to obstacles on the golf course such as bunkers or penalty areas (see 4.2.4 and 4.4.4). Therefore, not only is the golfer modifying their tee shot decision for fairway width, but they may also be avoiding obstacles. Figure 7 shows a reanalysis of the PGA TOUR data only looking at driving distance

as a function of fairway width and considering hole length (10). This different analysis found that 0.72 yards of distance decrease was observed per yard of decreased fairway width for players in elite male competitions on holes shorter than 450 yards. It confirms the relative insensitivity of average driving distance to fairway width for long holes.

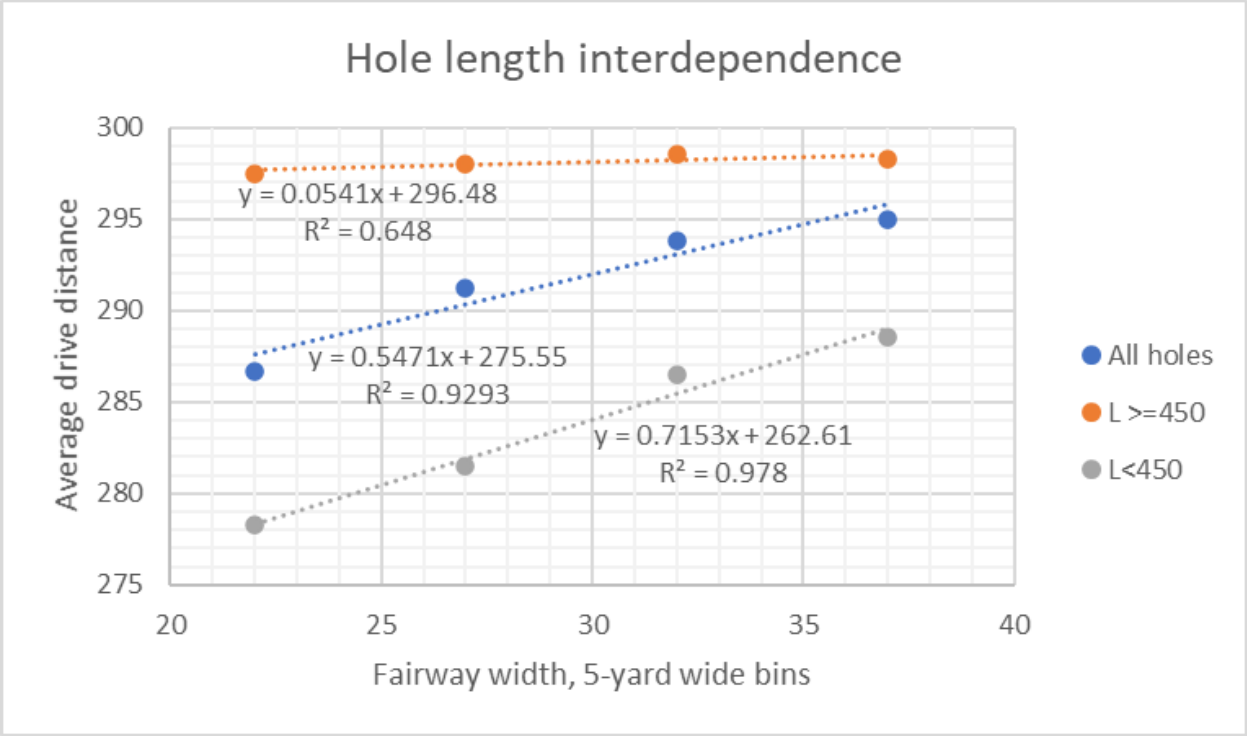

Figure 7: 2020-21 PGA TOUR DATA: AVERAGE DRIVING DISTANCE VERSUS FAIRWAY WIDTH CORRELATIONS BY HOLE LENGTH

Although not specifically studied and quantified, the hole length for recreational golfers that would change their behavior will be relative to their hitting distance and different than elite golfers - typically much less than 450 yards for most golfers.

4.3.5.2 Feasibility and Applicability

Narrowing fairways is something that could be considered at most courses. Cost and practicality depend on existing grass types in the fairways and rough, along with the irrigation layout and location of obstacles. Narrowing fairways can involve significant expense depending on the grass types, irrigation layout, and timeframe for modifications. Narrowing fairways also has the potential to reduce golfer satisfaction if the changes are permanent and accompanied by overly challenging rough.

4.3.6 Rough Penalty

4.3.6.1 Distance Impact Per Hole

The impact on driving distance from increased rough penalty was another of several golf course hitting distance factors that were studied during a statistical analysis project by Broadie (8) using the same data as described in Section 3.2. Here, Rough Penalty is defined by the change in strokes gained between a fairway lie and a rough lie at the same approach distance. The statistical model coefficients and statistical significance for the penalty of rough are shown in Table 6.

Parameter	Coefficient Estimate	Std. Error	t-Statistic	p-Value
Rough vs. Fairway	-4.74	0.505	-9.39	<0.001

*All variables are significant at the 1%

Table 6: AVERAGE DRIVING DISTANCE STATISTICAL ANALYSIS FOR ROUGH PENALTY

Values of Rough Penalty in the period studied for elite male competitions (8) varied from in -0.1 to -0.5. For the greatest Rough Penalty, tee shots were as much as 2 yards shorter than those for the least Rough Penalty. Fairway width and hole length are related factors for this distance impact. Wider fairways may generally lead to less concern about the penalty from difficult rough, and longer holes will lead to increased use of driver regardless of the penalty.

Rough height as an independent factor was studied in a separate analysis of elite male competitions (5) and found not to be a quantitatively significant effect on drive distance. The effect was less than 1 yard per inch of rough height.

4.3.6.2 Feasibility and Applicability

Increasing rough penalty is feasible at all golf courses through agronomic changes.

4.4 Design-related distance factors

4.4.1 Overall Context

This section focuses on design factors. Design factors can generally be changed during the initial construction of the course or during a renovation and generally at higher cost than setup or conditioning adjustments. Design changes are typically longer-lasting adjustments, which means their impact on long-term maintenance costs and the golfer experience of a wide range of players should be carefully considered.

4.4.2 Modifying Landing Zone Pitch

4.4.2.1 Distance Impact Per Hole

A detailed bounce and roll study was completed in support of Distance Insights (9). 0.98-2.45 yards of decreased tee shot distance was observed for every degree that landing zone pitch is tilted into the tee shot. When fairway landing zone pitch exceeds approximately 6 degrees uphill, there is a strong possibility that the ball may not come to rest and is likely to roll

backward. The upper limit on playable fairway grades will influence how much distance modification is possible on a particular hole.

4.4.2.2 Feasibility and Applicability

Modifying the grade of a landing zone to decrease bounce-and-roll after impact generally requires a large area of disturbance and significant costs for a modest decrease in distance, which likely makes this change infeasible for most courses. However, paying attention to the relationship between back tee hitting distances and landing zone pitch during new construction or renovation could present opportunities to make a course play longer without incurring significant additional costs.

4.4.3 Modifying Tee to Landing Zone Elevation Change:

4.4.3.1 Distance Impact Per Hole

Trajectory simulations were used to determine the effect of elevation change between the tee area and the landing zone of drives (11) and were confirmed by Broadie (8). It was found that there was 0.2 yards of decreased tee shot distance for every 1 foot of landing zone elevation increase or tee height decrease. Distance impacts through cut-and-fill modifications in the landing zone or back tee area will be limited because of the earthmoving required. This factor is likely to be most impactful during course routing, large-scale renovations, and during setup for events where there is a desire for the course to play longer.

4.4.3.2 Feasibility and Applicability

The earthmoving required to achieve meaningful distance impacts is impractical in most cases. Significant elevation changes on the property are required to achieve distance impacts through course layout or setup relating to tee shot elevation changes. Properties with limited elevation change will not be able to impact hitting distance in a significant way through tee to landing zone elevation relationships.

4.4.4 Placing Penalty Areas Near the Landing Zone (Physical Obstacles)

4.4.4.1 Distance Impact Per Hole

As described in section 4.2.4, driving distance change from placing a penalty area near the landing zone was another of several golf course hitting distance factors that were studied during a statistical analysis project by Broadie (8) using the same data as described in Section 3.2. The statistical model coefficients and statistical significance are shown in Table 3. The study found 4.5 yards of decreased tee shot distance when a penalty hazard is located near the landing zone in a way that creates a relatively high risk (>2.5%) of incurring a penalty.

Distance effects can be increased by creating cross-hazards, which essentially limit distance to whatever degree desired. When the risk of incurring a penalty decreases, the effect on average driving distance decreases and eventually has no effect on average driving distance.

4.4.4.2 Feasibility and Applicability

Placing physical obstacles that are penalty areas – e.g., a pond – as a design feature near the landing area during the initial design or during renovation is a common practice. However, the feasibility drops substantially after initial design and between major renovations. The golfer experience impact of penalty areas must be carefully considered because even those located in the landing zone for longer hitters must eventually be avoided by all golfers playing the hole.

4.4.5 Modifying Hole Length (adding tees)

4.4.5.1 Distance Impact Per Hole

Modifying hole length within the available tees was described in the Setup Effects section (4.2). Another way to modify hole length is to add new tees to a hole which will affect hitting distance consistent with setup changes.

4.4.5.2 Feasibility and Applicability

Adding back tee yardage typically requires building a new teeing area, which can involve varying degrees of intervention depending on the existing site conditions. Adding a back tee into an existing turf area with irrigation coverage can be a relatively small-scale project, while adding a back tee into a forested area with steep slopes would require a much larger scope of work and higher costs. Moving tee locations forward or back can have safety implications for players on that hole or on adjacent holes. Also, not all golf courses have space available or means to add back tees and this type of modification has impacts on golf course footprint and long-term resource consumption.

5 Conclusions

This document and supporting materials include research conducted regarding golf course effects on hitting distance as recommended in the February 4, 2020, Distance Insights Statement of Conclusions (1). While the setup, course condition and design factor interactions with hitting distance are complex, interrelated and highly variable dependent on specific golf course site conditions, quantitative ranges have been estimated for the most significant effects. These factors have modest and varying degrees of impact on distance and a wide range of potential cost and golfer experience effects. Therefore, they should not be viewed as a means to substantially reduce the long-term impact related to distance across the game. These potential practices will continue to be reviewed as part of the ongoing conversation with the industry on hitting distance.

6 References

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